

Appendix C

Environmental Sampling Instructions

C.1 Sampling Strategies

C.1.1 Scope and application. This instruction discusses strategies that can be employed to sample various media, including but not limited to soils, sediments, or water. Several different types of sampling strategies exist that can be categorized as either statistical or nonstatistical methods. Applications and limitations of each sampling strategy will be briefly described.

C.1.2 Sampling strategies. One of the main goals of any investigation is to collect samples that are representative of the site conditions so that an accurate assessment of contamination can be made with a minimum number of samples. Based on the conceptual site model (CSM), crucial pathways and media requiring assessment are identified, and are later used to evaluate whether the data make sense for what is known about the site. The various sampling strategies available can be grouped into two basic categories: statistical and nonstatistical methods. To ensure that samples are as representative as possible, statistics are often used to design an appropriate sampling strategy and to provide a sound basis for supporting project decisions. Depending on data needed to support project decisions, input from an environmental statistician may be obtained. In addition, software programs (e.g., DQO Pro, DEFT, DataQuest, Visual Sampling Plan) are available to aid in the evaluation of various sampling scenarios and the uncertainty associated with them. Classical statistical methods are most applicable to sampling media that are considered fairly homogeneous (e.g., ground water, surface water). However, because of the spatial variability of soils, application of sampling strategies using classical statistical techniques may be limiting. The use of geostatistical methods is recommended for sediments and soils to account for the variability of the media. A related factor to consider is the distribution of the contaminant within the environmental medium, and how this may impact the use of the data or what is considered representative. Information on how the contaminant was dispersed at the time of waste generation, spill, or discharge may help in assessing whether the contamination is present on a molecular scale (e.g., solvent or solution spills) or on a macroscale (e.g., lead shot, ammunition debris, and TNT chunks). The latter situation increases the likelihood that samples may exhibit a high short-range heterogeneity, and the challenge of obtaining representative samples becomes even more difficult. The use of compositing and homogenizing techniques can improve representativeness of the samples (i.e., when amenable to the eventual physical/chemical analyses) by invoking the physical process of averaging. Refer to Instructions E-2 and E-3 of Appendix E for additional information on homogenizing and compositing techniques and to E-4 for information on the collection, handling, and storage of solid volatile organic analysis (VOA) samples. Statistics can also be used to determine the number of samples required to reach a prescribed level of uncertainty. However, when statistical calculations result in an unacceptably high number of samples being defined, the use of field analytical technologies or field screening techniques should be pursued to reduce the cost of sample analyses while maintaining a desired level of site coverage. Refer to Appendix H for additional information on this subject. Typically, more than one sampling strategy or approach is necessary when several media or types of contamination are under investigation, and most sampling plans employ a combination of sampling strategies. The following text and Table C-1 summarize basic descriptions, applications, and limitations for some frequently used sampling strategies. Additional references are also included to provide more detailed discussions on the subjects.

C.1.2.1 Classical statistical sampling. A discussion of statistical sampling is presented in the following sections. For a detailed discussion of classical statistical methods see U.S. Environmental Protection Agency (USEPA) EPA/530/SW-89/026, EPA/SW-846 (Volume II), Gilbert (1987), and Pitard (1993).

Table C-1
Comparison of Sampling Strategies

Sampling Strategy	Description	Application	Limitations
Classical Statistical Sampling Strategies			
Simple random sampling	Representative sampling locations are chosen using the theory of random chance probabilities.	Sites where background information is not available and no visible signs of contamination are present.	May not be cost-effective for samples located too close together. Does not take into account spatial variability of media.
Stratified random sampling	Site is divided into several sampling areas (strata) based on background or site survey information; each stratum is evaluated using a separate random sampling strategy.	Large sites characterized by a number of soil types, topographic features, past/present uses, or manufacturing/storage areas.	Often more cost-effective than random sampling. More difficult to implement in the field and analyze results. Does not take into account spatial variability of media.
Systematic grid sampling	Most common statistical strategy; involves collecting samples at predetermined, regular intervals within a grid pattern.	Best strategy for minimizing bias and providing complete site coverage. Can be used effectively at sites where no background information exists. Ensures that samples will not be taken too close together.	Does not take into account spatial variability of media.
Hot-spot sampling	Systematic grid sampling strategy tailored to search for hot spots.	Sites where background information or site survey data indicate that hot spots may exist.	Does not take into account spatial variability of media. Trade-offs between number of samples, chance of missing a hot-spot, and hot-spot size/shape must be weighed carefully.
Geostatistical approach	Representative sampling locations are chosen based on spatial variability of media. Resulting data are analyzed using kriging, which creates contour maps of the contaminant concentrations and the precision of concentration estimates.	More appropriate than other statistical sampling strategies because it takes into account spatial variability of media. Especially applicable to sites where presence of contamination is unknown.	Previous investigation data must be available and such data must be shown to have a spatial relationship.
Nonstatistical Sampling Strategies			
Biased sampling	Sampling locations are chosen based on available information.	Sites with specific known contamination sources.	Contaminated areas can be overlooked if they are not indicated by background information or visual signs of contamination. Best if used with statistical approach, depending on the project objectives.
Judgmental sampling	An individual subjectively selects sampling locations that appear to be representative of average conditions.	Homogeneous, well-defined sites.	Not usually recommended due to bias imposed by individual, especially for final investigations.

C.1.2.1.1 Simple random sampling. Simple random sampling is the most basic statistical approach and is usually applied when minimal site background information (e.g., past practices, uses of hazardous materials, etc.) is available and visible signs of contamination are not evident during the initial site survey. This strategy uses the theory of random chance probabilities to choose representative sampling locations. Each sample location is chosen independently of any previously chosen sample location. It is most effective when the number of available sampling points is large enough to lend statistical validity to the random selection process. The simple random sampling approach may be more costly than other statistical methods since a larger number of samples may be required to characterize the site.

C.1.2.1.2 Stratified random sampling. Investigations of large sites that encompass a number of soil types, topographic features, or land uses may benefit by using a modified random sampling approach, called stratified random sampling. In this strategy, the site is divided into different sampling areas (strata) that are internally homogeneous based on existing data and background information. The division of the site into strata is based on the assumption that each stratum is more internally homogeneous than the site as a whole. Each stratum is sampled at locations based on a simple random sampling approach. By grouping similar sampling points and treating each group separately, each with its own individual random sampling scheme, the precision of the study is increased. In addition, this approach controls the variability due to contaminant concentration, location, terrain type, etc., and it often results in more efficient allocation of resources than would be possible with a simple random sampling method. Sampling analyses from each stratum may be used to determine the mean or total contaminant concentration within the stratum. However, data from each stratum may be used to make comparisons between the different strata or combined to provide information about the entire site.

C.1.2.1.3 Systematic grid. Systematic grid sampling, sometimes referred to as systematic random sampling, is the most common statistical sampling strategy. It involves collecting samples at predetermined, regular intervals (i.e., within a grid pattern). The location of the first sampling point is selected at random and all subsequent sample locations are determined using a systematic pattern from that point. This approach is typically used when a large site (e.g., measured in acres) must be sampled to characterize the presence and distribution of contaminants. The grid-based option is probably the best classical statistical sampling strategy for minimizing bias and providing complete site coverage. The most basic grid system is a straight line between two points on which regularly spaced sampling locations are designated. This one-dimensional sampling grid may be used for sampling along a straight drainage ditch or other man-made feature. However, most soil sampling schemes require a two-dimensional grid system for locating sampling points. The following types of grids are generally used: square, triangular, or other systematic pattern. Sampling is usually performed at each grid-line intersection. However, sampling in the center of each grid square/triangle or obtaining a composite of samples within a grid square/triangle is also acceptable.

C.1.2.1.4 Hot-spot sampling. “Hot spots” are usually defined as small, localized areas of a media that are characterized by high contaminant concentrations. In order to detect hot spots, a special systematic grid sampling approach is necessary. However, because all of the media cannot be sampled, there is still a possibility that hot spots exist even if none are discovered during the sampling process. Statistical approaches for detection of hot spots are discussed in Gilbert (1987). A hot-spot sampling plan should consider the following factors:

- Grid spacing and geometry. A triangular grid pattern increases the efficiency of the hot-spot search. In addition, the probability of finding hot-spots increases as the spacing between grid points decreases.
- Hot-spot shape/size. The larger a hot spot is, the more likely it is to be discovered. The shape of the hot spot also affects the probability of its being detected. Narrow or small-circular patterns may escape detection because they are located between grid sampling locations. Large-circular and wide-elliptical hot spots are the easiest to find.
- False negative rate. This measures the probability that a hot spot will be missed even if one is present.

C.1.2.1.5 Geostatistical approach. Classical statistical methods for the design of sampling projects are well-known and have been the standard approach in the past. However, these strategies have one major

drawback—they do not take the natural variability of the media into account. As such, they may not adequately characterize contamination at sites, especially those sites that are fairly heterogeneous and/or where the presence of contamination is unknown. Consequently, classical statistical methods are most appropriately applied to sites where the source of contamination is known (e.g., a landfill, waste pile, etc.) or small sites where the entire area is to be remediated as a unit (e.g., in the case of soils, the entire site will be solidified). To more accurately characterize sites where the presence of contamination is unknown, statisticians now believe that geostatistical methods are more appropriate than classical statistical methods because they take into account the spatial variability of the media when estimating contaminant concentrations. Geostatistical methods may be used for sampling naturally occurring materials such as soils or ground water and man-made units such as landfills or waste piles. Characterization of any media is difficult because contaminant levels are spatially correlated. This means that contaminant concentrations from samples taken close together are more likely to be similar than contaminant concentrations from samples taken farther apart (regional variability). Geostatistics describes how to sample and analyze regional variability by defining the representativeness of a sample in terms of its range of correlation or zone of influence. For example, a sample location selected through geostatistics will represent a circular area with a radius less than or equal to the zone of influence. In other words, the sample would be representative of the media within the circular area. A two-stage sampling approach is typically used in geostatistical sampling strategies. Initially, a sampling survey is performed to collect basic data. These data are used to create a graph that defines the distance over which samples are representative. This graph is then used to dictate the shape, size, and orientation of another systematic grid that is used in the second, final sampling event. Geostatistical sampling strategies are relatively complex, and further discussions of this approach are found in Engineer Technical Letter (ETL) 1110-1-175, Borgman and Quimby (1988), and Gilbert (1987).

C.1.2.2 Nonstatistical sampling. Types of nonstatistical sampling are described as follows.

C.1.2.2.1 Biased sampling. Biased sampling is used to evaluate sites with specific, known sources of contamination (e.g., the site survey discovered visible signs of contamination or records indicate that certain locations are suspect based on past/present practices). As such, sampling locations are chosen based solely on available information.

C.1.2.2.2 Judgmental sampling. In judgmental sampling schemes, an individual subjectively selects the sampling locations that appear to be representative of average conditions. If the individual is knowledgeable, judgmental sampling can result in accurate estimates of site conditions. Although a certain amount of judgment is necessary in any sampling approach, total reliance on judgment decisions is not recommended because an individual's bias often leads to poor quality data and improper conclusions. However, if judgmental sampling is necessary, multiple samples should be collected to add some measure of precision.

C.1.3 Potential problem. Table C-1 shows the limitations associated with these sampling strategies.

C.2 Ground Water Sampling

C.2.1 Scope and application. This instruction presents guidelines for collecting representative ground water samples from temporary and permanent ground water monitoring wells and, where applicable, from other direct push well screen samplers. Guidance for the installation of temporary wellpoints by direct push methods for sampling ground water at discrete points may be found in American Society for Testing and Materials (ASTM) D 6001. Typical ground water monitoring wells are 5 or 10 cm (2 or 4 in.) in diameter and are constructed of polyvinyl chloride (PVC) or stainless steel. Instructions presented herein are intended to include sample collection from wells that have not been completed as production or extraction wells. The instructions can be used to identify an appropriate sampling protocol for the acquisition of a representative sample. Instruction C-4, "Potable Water Sampling," includes procedures for sampling permanent production wells or any other well constructed with a discharge tap. Instructions for purging and sampling wells by the following techniques are included in this section: bailer, portable submersible pump, bladder pump, hand pump, centrifugal pump, peristaltic pump, air lift pump, and low-flow sampling.

C.2.2 Sampling strategies. Sampling strategies are developed by the project team to satisfy project-specific data needs identified in the hazardous, toxic, and radioactive waste (HTRW) technical planning process. The sampling strategy developed for a particular site will influence several project decisions, including, but not limited to, sampling locations, types of samples, sampling frequency, and sampling and analytical protocols. Sampling strategies may be significantly influenced by such factors as physical site constraints, safety, and cost, to name a few. The technical planning process that results in the development of the sampling strategy is critical because of the difficulty in acquiring representative samples, the reduction of contaminant action levels, and the problems associated with trace level cross-contamination. Successful investigations of hazardous waste sites are highly dependent on an effective sampling scheme. Development of a sampling scheme for purposes of characterizing a hazardous waste site should follow the fundamentals of the scientific approach. A successful sampling scheme requires a logical design to allow an evaluation of potential contaminants in relation to background conditions, vertical extent, horizontal extent, and mobility in various media. Additional guidance may be found in ASTM D 5903.

C.2.2.1 Sampling locations. Sampling at hazardous waste sites is usually conducted in an attempt to identify contamination and to define its extent and variability. With such an objective, it is most logical to choose sample locations that will yield the most information about site conditions. During evaluation of a site, sampling can be conducted by random, systematic, or biased sampling. Instruction C-1 discusses random, systematic, and biased sampling in detail. Often biased and random sampling techniques can be used together to thoroughly address an entire site. Some wells may be biased to potentially contaminated areas (e.g., former wastewater lagoons, former process or disposal areas), or potentially impacted areas (e.g., down-gradient locations). In areas less likely to be contaminated or areas with little available background information, random samples may be used to allow adequate assessment of the entire site. Ground water monitoring wells are positioned at locations and depths to satisfy ground water monitoring objectives. Ground water samples collected from monitoring wells are evaluated as discrete samples collected from the same location. Ground water samples collected from the same well are distinguished from one another because they are distributed through time. Unless each ground water monitoring well has a sampler dedicated to the well, the order of sampling monitoring should be from the least contaminated to the most contaminated.

C.2.2.2 Sample type. Ground water samples are typically discrete samples. A discrete (grab) sample is a discrete aliquot representative of a specific location at a given point in time. The sample is collected at once and at a particular point in the sample matrix. The representativeness of such samples is defined by the nature of the materials being sampled. In general, since contamination in ground water disperses over time and distance, it will take more grab samples to characterize the extent of contamination as the time from a release increases.

C.2.2.3 Suggested samplers. Each sampling technique presents various disadvantages and advantages for its application. For example, sample disturbance, sample volume, chemical/physical reactivity between potential contaminants and sampling tool materials, well diameter, depth to ground water, limitations of lift capacity of the sampling device, specified analytical parameters, and ease of decontamination vary from technique to technique. The advantages and disadvantages of each sampling technique are presented in the discussion of the technique.

C.2.2.4 Sample frequency. Contaminant concentrations in ground water vary across both time and space. Therefore, it is important to consider the potential temporal variability of the data collected. Determination of the number of samples needed to characterize a site is dependent upon the objectives and the site-specific conditions. For example, if the objective of the event is to determine whether the site is contaminated, a limited number of samples from properly chosen locations will yield useful information. If, however, the site is contaminated and the objective is to establish the boundaries of the ground water contamination or trends in the data over time, a greater number of samples may be needed. Often statistical considerations can be helpful in determining sampling strategy.

C.2.3 Sample preservation and handling. Many chemical constituents and physicochemical parameters that are to be measured or evaluated in ground water monitoring programs are not chemically stable, and therefore sample preservation is required. Appropriate preservation techniques for various parameters and sample containers that should be used for each constituent or common set of parameters are specified in Appendix B. These preservation methods and sample containers are based on "Test Methods for Evaluating Solid Waste: Physical/Chemical Methods" (EPA/SW-846). Procedures and techniques for transporting the samples to the offsite laboratory are discussed in Instruction F-2 of Appendix F, "Packaging and Shipping Procedures." Improper sample handling may alter the analytical results of the sample, causing the results to be invalid. Samples should be transferred in the field from the sampling equipment directly into the container required for that analysis or set of compatible parameters. The sample should then be preserved in the field as specified in Appendix B. Because of the low analytical detection limits required for certain data uses, care must be taken when collecting the sample to avoid the loss/gain of any contaminants. The samples for volatile analysis should be carefully transferred directly from the sample collection device to the sample container to minimize contaminant loss through agitation/volatilization or adherence to another container. Samples should be collected in the order of the parameters listed in Section C.2.3.1. If more than one container is required per parameter, the sample should be split equally among all containers until filled. Containers used to collect samples for organic analyses should not be prerinsed with water because of the possibility of preservation loss or the loss/gain of contaminants that may taint the analytical results. Decisions to filter samples are dictated by sampling objectives. Consideration should be given to what the application of field filtration is trying to accomplish. For assessment of dissolved concentrations of major ions and trace metals, 0.1- μ m filters are recommended, although 0.45- μ m filters are normally used for most regulatory programs. In-line filtration is recommended because it provides better consistency through less sample handling and minimizes sample exposure to the atmosphere. Filters must be prerinsed following manufacturers' recommendations or using a minimum of 1 L of ground water following purging and before sampling. Further information on filtration considerations and consequences is given in Instruction E-1, Appendix E.

C.2.3.1 Sample containers. When metals are the analytes of interest, high-density polyethylene containers with polytetrafluoroethylene-lined polypropylene caps should be used. (Polytetrafluoroethylene is commonly referred to using the registered name of Teflon. Polytetrafluoroethylene will be referred to as PTFE.) When organics are the analytes of interest, glass bottles with PTFE-lined caps should be used. Refer to Appendix B or the specific analytical method for acceptable containers. Containers should be cleaned based on the analyte of interest. Instruction E-6, "Decontamination Procedures" (Appendix E), contains

additional information on appropriate glassware cleaning protocols. If precleaned bottles are used, the cleanliness of each lot of precleaned bottles should be verified by the container supplier or in the laboratory and appropriate paperwork (i.e., certificates) retained with other field documentation. Refer to Appendix B for information on the required size and type of sample containers. Samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. The following is a preferred collection order for some common ground water parameters:

- Volatile organics (VOA)
- Purgeable organic carbon (POC)
- Purgeable organic halogens (POX)
- Total organic halogens (TOX)
- Total organic carbon (TOC)
- Extractable organics
- Total metals
- Dissolved metals
- Phenols
- Cyanide
- Sulfate and chloride
- Turbidity
- Nitrate and ammonia
- Radionuclides

C.2.3.2 Sample preservation. Methods of sample preservation are relatively limited and are generally intended to retard biological action, retard hydrolysis, and reduce sorption effects. Preservation methods are generally limited to pH control, chemical addition, cooling, and protection from light. Prepreserved sample containers are not recommended. Because different amounts of preservative may be necessary to bring the sample to the required pH, it is recommended to add the preservative to the container in the field and to verify that the pH of the sample has been achieved. This information should be documented within field logbooks. The sampler should refer to Appendix B or the specific preservation method in EPA/SW-846 for the appropriate preservation technique.

C.2.3.3 Special handling for VOA samples. Water samples to be analyzed for purgeable organic compounds should be stored in 40-mL vials with septum inserts and screw caps. The septum should be placed on the sample vial so that the PTFE side is in contact with the sample. The 40-mL vials should be completely filled to prevent volatilization. Extreme caution should be exercised when filling a vial to avoid any turbulence that could also produce volatilization. The sample should be carefully poured down the side of the vial to minimize turbulence. As a rule, it is best to pour the last few drops into the vial gently so that surface tension holds the water in a convex meniscus. The septum is then applied and some overflow is lost, but air space in the bottle is eliminated. After the bottle is capped, it should be turned over and tapped to

check for bubbles. If any bubbles are present, the procedure must be repeated. Care should be taken to ensure that no loss of preservative occurs, if applicable.

C.2.3.4 Special precautions for trace contaminant sampling. Contaminants can be detected in the parts per billion and/or parts per trillion ranges. Therefore, extreme care must be taken to prevent cross-contamination of these samples. The following general precautions should be taken when sampling:

- A clean pair of new disposable gloves should be worn each time a different location is sampled, and gloves should be donned immediately before sampling.
- To prevent cross-contamination between samples, it is suggested that the multiple VOA vials from each sampling location be sealed in a separate smaller plastic bag when the sampled medium is suspected of containing high concentrations of volatile organics.
- Sample containers filled with source or waste samples or samples suspected of containing high concentrations of contaminants should be placed in separate plastic bags immediately after collecting and preserving, and activated carbon should be included in the bags to prevent cross-contamination.
- If possible, background samples and source samples should be collected by different field teams. If different field teams cannot be used, all background samples should be collected first and placed in separate ice chests or shipping containers. Samples of waste or highly contaminated samples should never be placed in the same ice chest as environmental samples. It is good practice to enclose waste or highly contaminated samples in a plastic bag before placing them in ice chests. Ice chests or shipping containers for source samples or samples suspected to contain high concentrations of contaminants should be lined with new, clean plastic bags.
- If possible, one member of the field team should take all the notes, fill out sample tags, field sheets, etc., while the other members collect all of the samples.
- Sample collection activities should proceed progressively from the suspected least contaminated area to the suspected most contaminated area.
- Field personnel should use equipment constructed of PTFE, stainless steel, or glass that has been properly precleaned. PTFE or glass is preferred for collecting samples where trace metals are of concern.
- Adequate field control samples should be collected.

C.2.4 Sampling methods. Sampling instructions for the most common techniques for collecting ground water samples from ground water monitoring wells are presented in this section. A summary of the methods is presented in Table C-2. Additional information is presented in EPA/540/S-95/504, EPA/625/R-93/003a, ASTM D 4448, ASTM D 6232, and ASTM D 6452. Additional information on the installation, development, and decommissioning of monitoring wells can be found in ASTM Standards D 5092, D 5299, and D 5521. After installation, the well should be developed to remove any fine material adjacent to the well casing. Wells should not be sampled immediately after development, due to the time needed to reach chemical equilibrium with the well construction materials. This lag time may often extend beyond 1 week. Consequently, well development is not addressed in this sampling and analysis guidance document. Refer to EM 1110-1-4000 for further information on well development. Once a well has been

Table C-2
Summary of Ground Water Sampling Techniques

Method	Advantages				Disadvantages			
	Compatible Construction Material	Ease of Use	Economical	External Power Source Needed	VOC Degassing	Ease of Decontamination	Large Water Volumes	Restrictive Ground Water Depth
Bailer	•	•	•			•		
Submersible Pump	•			•	•		•	
Bladder Pump	•			•				
Hand Pump	•	•	•		•			
Centrifugal Pump			•	•	•		•	•
Peristaltic Pump	•			•	•	•		•
Air-Lift Pump		•		•	•		•	•
Passive Samplers	•	•	•					

located and properly identified, field measurements should be noted in a bound field logbook. A cross-reference should be made between the previously recorded physical location/identification locating the well to be sampled to ensure the proper well has been selected. Misidentification of a sampling point in the field will result in erroneous data that may affect management decisions. Also included in field measurements are the physical measurements of the well and its physicochemical parameters. Physical measurements that may be recorded in the field logbook include the presence and diameter of protective casing, diameter and construction material of the well casing, total depth of well from the top of casing, surveyors' mark, depth from top of casing to water, and the volume of water in the well and filter pack. The volume of water can be calculated by the submerged length of the well and calculating the volume of water in the submerged casing and filter pack. The total depth of the well should not be measured before sampling, but be obtained from well logs. Measuring to the bottom of the well casing may cause resuspension of settled solids from the formation materials and require longer purging times for turbidity equilibration. The well depth should be measured after sampling is complete. Volumes of water in various well casing diameters are listed in Table C-3.

Table C-3
Water Volume in Casing

Nominal Casing Diameter centimeters (inches)	Water Volume liters/linear meter (gallons/linear foot)
5.1 (2)	2.03 (0.16)
10.2 (4)	8.11 (0.65)
15.2 (6)	18.24 (1.47)
20.3 (8)	32.43 (2.61)
25.4 (10)	50.67 (4.08)
30.5 (12)	72.96 (5.88)

The volume of water in the filter pack should be calculated assuming a porosity of 30 percent within the filter pack. The volume of water present in the well casing and filter pack may be calculated as shown in the following example:

Assumptions: 2-in. well casing; well depth is 100 ft below ground surface, ground water depth is 20 ft below the ground surface, and the boring diameter is 8 in.

$$\begin{aligned}\text{Volume of water in well} &= (\text{well depth} - \text{depth to water}) \times (\text{water volume in casing}) \\ &= (100 - 20) \text{ ft } (0.1632 \text{ gal/ft}) \\ &= 13.0 \text{ gal}\end{aligned}$$

$$\begin{aligned}\text{Volume of water in filter pack} &= (\text{volume of filter pack}) \times 30\% / 231 \text{ in.}^3/\text{gal} \\ &= \{[(B) (8 \text{ in.})^2 / 2] \times 80 \text{ ft } (12 \text{ in./ft})\} \times 0.3 / 231 \text{ in.}^3/\text{gal} \\ &= 58.7 \text{ gal}\end{aligned}$$

$$\begin{aligned}\text{Total volume in well casing and filter pack} &= 13 \text{ gal} + 58.7 \text{ gal} \\ &= 71.7 \text{ gal}\end{aligned}$$

The volume of water in any size casing can be determined using the following formula:

$$\text{No. of gallons} = 5.8752 \times C^2 \times H$$

where C = casing diameter, ft

H = height of water column, ft

Besides the physical measurements taken as described previously and other information that may identify the well, physicochemical information such as dissolved oxygen, pH, specific conductance, temperature, and turbidity should be recorded initially (and in that order), during purging and before sampling (see Section C.2.4.1).

C.2.4.1 Well purging. To obtain a representative sample of ground water from a ground water monitoring well, the water that has stagnated and/or thermally stratified in the well casing must be purged or evacuated. The purging procedure allows fresh or representative ground water to enter the well. The optimum or preferred method to ensure that fresh water representative of the aquifer in contact with the well screen is being sampled is to perform a controlled sampling experiment. When indicator parameters such as specific conductance, pH, temperature, turbidity, and dissolved oxygen are stabilized, the well is presumed to be adequately flushed for the representative sample. In some instances, purging rates must be kept below 500 mL/min to avoid overpumping or pumping the well to dryness. Guidance on recommended stabilization criteria for the indicator parameters is included within the individual sampling equipment instructions. Ideally, wells should never be pumped to dryness. To accomplish this, pump rates may be adjusted, sometimes to less than 500 mL/min, and pumping times extended. Pumping with low-flow rates may also reduce the need for filtering water samples. Additional guidance on low-flow purging may be found in EPA/540/S-95/504. The volume of purging is significantly less in low-flow sampling, because the flow rate is designed to be low enough that flow is being induced only horizontally through the screen at a rate that replaces the evacuated water. This flow rate (typically 100-500 mL/min) will also have minimal effect on entraining particulates, which lowers the sample turbidity, which is crucial to metals analyses. The well can be purged or evacuated in several ways. In any instance it is paramount to ensure that the purging procedure does not cause cross-contamination from one well to the next. Therefore, the preferred method

employs dedicated equipment and pumps. Because, commonly, it may not be practicable to dedicate a pump to a specific well, it is permissible to decontaminate this equipment, using approved methods. Tubing should always be dedicated and never used for more than one well. The selection of an evacuation method most often relies on the depth to water (DTW) in the well. If the static DTW is less than 7.6 m (25 ft), a hand pump or bailer may be the best method for evacuation. If the static DTW is greater than 7.6 m (25 ft), a submersible pump should be used. As mentioned earlier, care must be taken to ensure that this does not act as a route of cross-contamination. Pumps should be decontaminated between well locations. During evacuation, pump intake must not be set greater than 1.8 m (6 ft) below the dynamic water level. This requires that the evacuation device be lowered as purging continues and the water level drops. Hand bailing may be utilized with a static water level greater than 7.6 m (25 ft) if a submersible pump is not available or with a static water level less than 7.6 m (25 ft) if other conventional pumps are not available. However, use of a bailer is not recommended because it has the potential to aerate the well water, produce inadequate removal of fines, concentrate floating product on the bailer that may introduce contamination, introduce contaminants from inside the well casing, and cause nonsteady removal of water, which may result in dilution instead of evacuation of the well. In general, the mechanics of the hand-bailing method for well purging may introduce contamination potential and variability. There are many pumps that may be used for well purging. Not all pumps are acceptable under all conditions. The preferred and most commonly used pumps are centrifugal and peristaltic pumps (when depth to water is less than 7.6 m (25 ft)) and submersible pumps (when depth to water is greater than 7.6 m (25 ft)). Information on various pumps and methods of purging is provided later in this instruction. Recent studies have found that some in situ ground water sampling devices minimize or eliminate the need for purging (EPA/600/S4-90/028). These devices are stand-alone systems installed directly into the subsurface and are not used to sample existing ground water monitoring wells. For existing ground water monitoring wells, innovative samplers have been developed that sample the ground water monitoring well without the need to purge the well initially. These diffusion samplers have shown through case studies to be an effective means of acquiring volatile organic compound (VOC) samples (Vroblesky and Hyde 1997). Occasionally, a light, nonaqueous phase layer (LNAPL) (floating product) may be present in a monitoring well designated for sampling. If it is suspected that the well contains an LNAPL, an interface probe should be used to verify its presence. If an LNAPL is present, the thickness should be measured and an appropriate inert bailer should be used to collect a sample of the floating product. Whenever possible, measurements of the free product should be taken using either steel tape and paste or an interface probe. A bailer can significantly under- or overestimate the thickness of free product in the well and should not be used for determining the elevations of air/free product and free product/water interfaces. The use of bailers should be limited to verification of the presence of free product in a well or collection of a sample of it (EPA/510/R-96/001). Collection of a ground water sample may not be appropriate if an LNAPL is present in the well, for the sampler will likely become contaminated as it passes through the LNAPL to reach and sample the ground water below.

C.2.4.2 Bailers. Bailers are one of the simplest and most commonly used sampling methods for sampling ground water monitoring wells (Figure C-1).

C.2.4.2.1 Applicability. Bailers are constructed of a variety of materials compatible with the parameter of interest. They are economical and convenient enough that a separate bailer may be dedicated to each well to minimize cross-contamination. An external power source is not required. Bailers provide a low surface-to-volume ratio, which reduces degassing of VOCs. Cross-contamination can be a problem if the bailer is not adequately decontaminated. Bailers offer a relatively limited sample volume and may not be desirable for purging a well if large amounts of water need to be removed from the well for purging. The sampling technique used with bailers may, however, cause a surging action on the well, which may increase the turbidity of the well sample. Consequently, bailers have a higher potential for loss of volatiles and are not recommended for either volatile or metals sampling. Where representative numbers for metals and

volatiles are required, it is recommended that the low-flow procedures detailed in Section C.2.4.9 be utilized.

C.2.4.2.2 Method summary and equipment. Bailers are manufactured in numerous types, sizes, and construction materials. Bailers are typically weighted lengths of pipe attached to a cord with a check valve at the lower end. They are typically constructed of PVC, PTFE, or stainless steel. The PTFE bailer is recommended if the bailer is used to collect ground water samples for VOC analysis. Bailers can be dedicated to a specific well, i.e., used only for purging and sampling that well. Dedicated bailers are typically stored to prevent cross-contamination or, less preferably, left hanging in the well itself. It should be noted that stainless steel bailers left stored in a well will likely rust under high-humidity conditions. The bailer should be decontaminated after each use. Disposable bailers are also available and are cost-effective for certain investigations. Haul lines for bailers may consist of PTFE-coated stainless steel cable, polyethylene rope, or nylon rope. Of these three, nylon rope is the least desirable because it may introduce contaminants. The use of braided rope is discouraged, because it cannot be decontaminated. For each sampling event, the rope for dedicated bailers should be changed following purging and before sampling. For nondedicated bailers, rope should be changed between wells. After removal, the rope should be properly discarded.

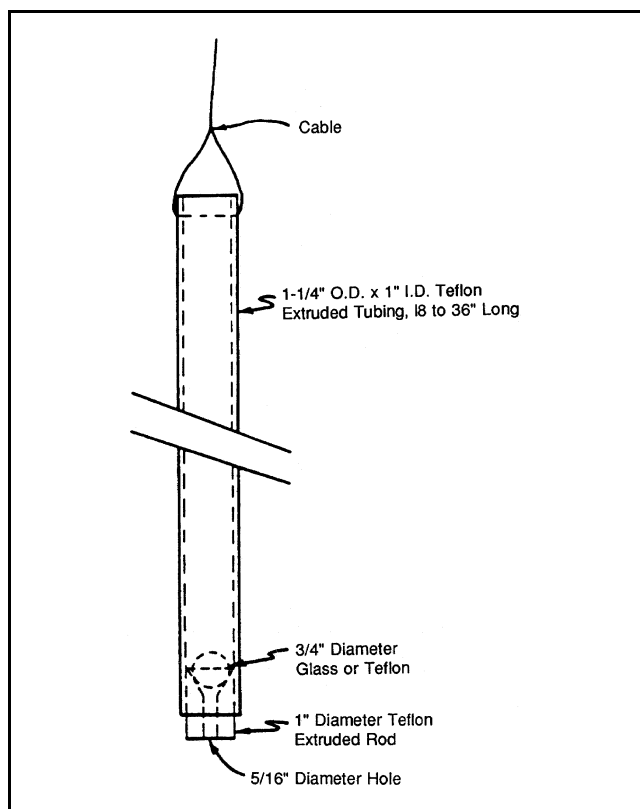


Figure C-1. Bailer (to convert dimensions to mm, multiply by 25.4)

For each sampling event, the rope for dedicated bailers should be changed following purging and before sampling. For nondedicated bailers, rope should be changed between wells. After removal, the rope should be properly discarded.

C.2.4.2.3 Sampling procedure.

- C Prepare the work area outside the well by placing plastic sheeting on the ground to avoid cross-contamination.
- C Determine the saturated water column in the well using an electronic water level indicator. Calculate the fluid volume in the casing and determine the amount of water to be removed for purging.
- C Attach a decontaminated bailer to cable or line for lowering, or use dedicated bailer already in well.
- C Lower bailer slowly until it contacts water surface.
- C Allow bailer to sink and fill with a minimum of surface disturbance.
- C Slowly raise bailer to surface. Do not allow bailer line or bailer to contact ground.

- C Purge well until the dissolved oxygen (DO), pH, specific conductance, temperature, and turbidity are each at equilibrium, and begin sampling. Equilibrium is established as follows: ± 10 percent for DO, ± 0.2 pH units, ± 3 percent for specific conductance, ± 1 degree Celsius for temperature, and ± 10 percent for turbidity. (If redox potential is used as an indicator, ± 10 mV should be used as the stabilization criterion.)
- C Ensure that equilibrium is established by making three consecutive readings, where one casing volume is pumped between each reading.
- C Collect VOA samples first following guidelines specified within this appendix.
- C Fill sample bottles for remaining parameters by tipping bailer to allow slow discharge from top to flow gently down the side of the sample bottle with minimum entry turbulence. If a bottom drain is present on the bailer, recommended that a slow steady flow be achieved.
- C Repeat these steps as needed to acquire sufficient volume to fill all sample containers.
- C Preserve the sample as necessary and verify that the pH is sufficient for the criteria.
- C Verify that a PTFE liner is present in the cap. Secure the cap tightly.
- C Label the sample bottle with an appropriate label. Be sure to include all necessary information.
- C Place filled sample containers on ice immediately along with the required trip blank, if analyzing for VOCs.
- C Record the information in the field logbook and field sheet, and complete all chain-of-custody documents (see Instruction F-1, "Documentation," in Appendix F).
- C Thoroughly decontaminate the bailer after each use, regardless of whether the bailer is dedicated to one well or used to sample other wells.
- C Close well.

C.2.4.3 Portable submersible pump. Portable submersible pumps are an effective technique for pumping large volumes of water at a steady rate but require an external electrical power source.

C.2.4.3.1 Applicability. Advantages of submersible pumps include their ability to pump variable amounts from various depths. This advantage makes these pumps applicable not only for purging and sampling but also for aquifer characterization tests. Pumping rates for various units range from as little as 100 mL per minute to 3,784 L per minute (1,000 gpm). The pumping rate for most units can be individually adjusted. Disadvantages of submersible pumps are that they require an external electrical power source and may be difficult to decontaminate between wells. The propeller construction of the pump assembly may cause degassing of volatile organic compounds; therefore, some states or USEPA regions may restrict the use of submersible pumps when sampling for VOCs.

C.2.4.3.2 Method summary and equipment. For submersible pumps, the pump assembly, the electric drive motor, and associated hoses and electrical cables are suspended from a steel cable or discharge pipe and submerged in the well. Intake is typically located between the motor and the pump assembly.

Horsepower, head, and lift capacity range widely. Submersible pumps are available for 5-cm (2-in.) and larger wells. Some pumps are constructed of stainless steel and PTFE to maintain sample integrity. Submersible pumps far exceed the pumping limitations of other sampling equipment.

C.2.4.3.3 Sampling procedure. Recommended sampling procedures are as follows:

- C Prepare the work area outside the well by placing plastic sheeting on the ground to avoid cross-contamination.
- C Determine the saturated water column in the well using an electronic water level indicator. Calculate fluid volume in the casing and determine the amount of water to be removed for purging.
- C Lower the decontaminated pump to below the water level and begin pumping. Collect or dispose of purged water in an acceptable manner. Lower the pump as required to maintain submergence.
- C Measure rate of discharge frequently. A bucket and stopwatch are commonly used.
- C Purge well until the DO, pH, specific conductance, temperature, and turbidity are each at equilibrium, and begin sampling. Equilibrium is established as follows: ± 10 percent for DO, ± 0.2 pH units, ± 3 percent for specific conductance, ± 1 degree Celsius for temperature, and ± 10 percent for turbidity. (If redox potential is used as an indicator, ± 10 mV should be used as the stabilization criterion.)
- C Ensure that equilibrium is established by making three consecutive readings, where one casing volume is pumped between readings.
- C Reduce the pump discharge rate to less than 500 mL/min. Collect VOA samples first following guidelines specified within this appendix.
- C Fill bottles for remaining parameters by allowing pump discharge to flow gently down the side of the bottle with minimal entry turbulence. Cap each bottle as filled.
- C Preserve the sample as necessary and verify that the pH is sufficient for the criteria.
- C Ensure that the PTFE liner is present in the cap. Secure the cap tightly.
- C Label the sample bottle with an appropriate label. Be sure to complete the label with all necessary information.
- C Place filled sample containers on ice immediately, along with the required trip blank, if analyzing for VOCs.
- C Complete chain-of-custody documents, field logbook, and field sheet (see Instruction F-1, "Documentation," in Appendix F).
- C Pull pump and allow system to drain and decontaminate.
- C Close well.

C.2.4.4 Bladder pump. Bladder pumps employ a closed collection system that eliminates agitation and air or gas contact with the sample (Figure C-2).

C.2.4.4.1 Applicability. Advantages of the bladder pump include its ideal design for sampling wells as small as 5 cm (2 in.) in diameter. The pump can pump water from various depths and at adjustable rates. It can operate in low-yielding wells without the possibility of burning out the pump if the well is pumped dry. The inlet for the pump body is typically at the lower end, thus requiring minimum submergence. Top-ended inlet pumps are also available for floating product recovery. Disadvantages of the bladder pump include its relatively low pumping rate. It also requires an outside power source of compressed air or gas and may be difficult to decontaminate between wells.

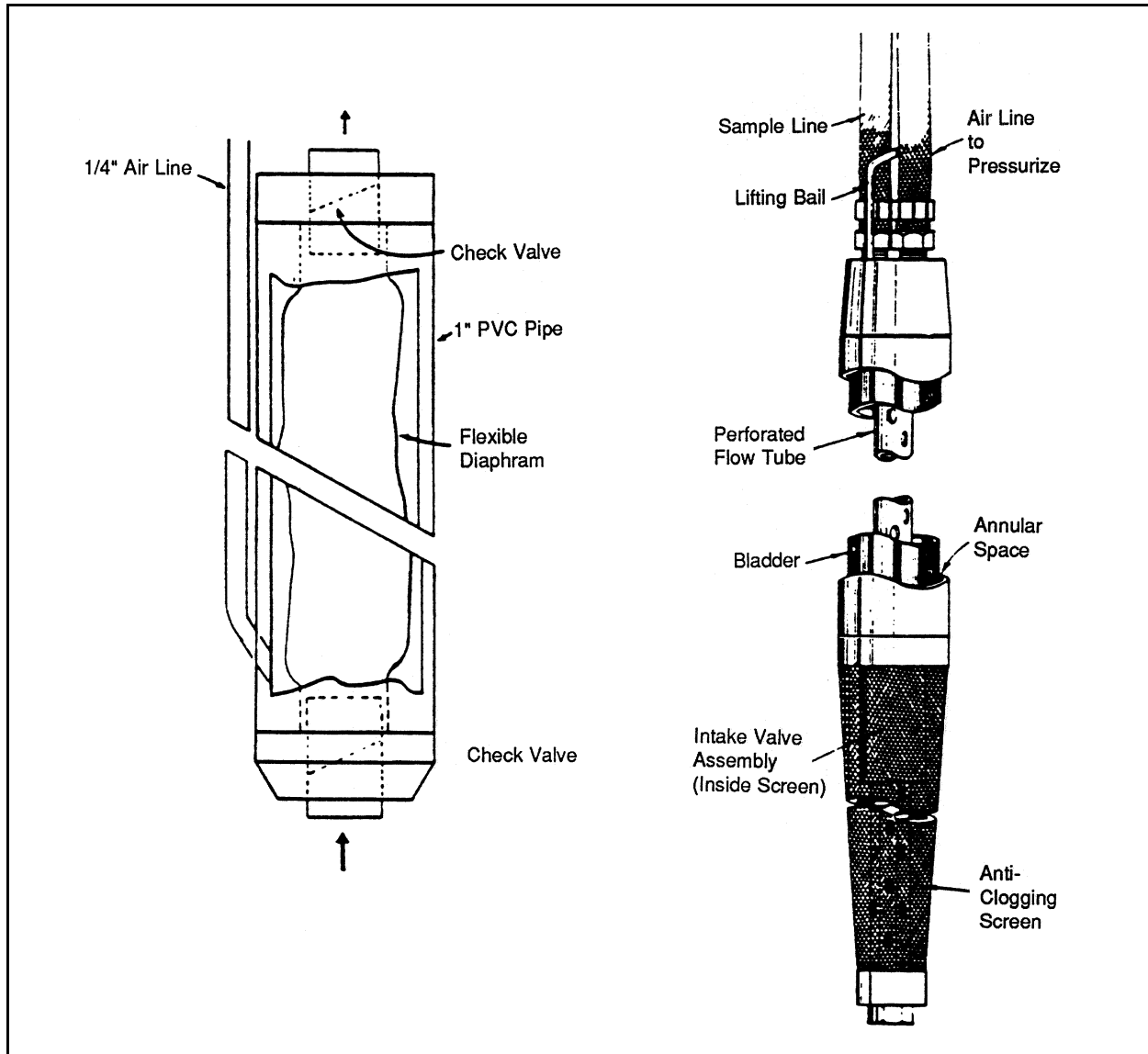


Figure C-2. Bladder pump (to convert dimensions to mm, multiply by 25.4)

C.2.4.4.2 Method summary and equipment. The closed system provides the best method available for sampling wells for VOCs. The pump fills through a lower check valve under hydrostatic pressure, collapsing the bladder in the pump body. The bladder is then pressurized with gas or air causing it to expand, thus applying pressure in the pump body. The bladder is pressurized using a control box and air compressor assembly. This in turn closes the lower check valve and forces the contents of the pump body up through the sample line check valve. Venting the bladder will allow the pump to refill and begin another cycle. An inflatable packer is often used in conjunction with bladder pumps to reduce the amount of water to be purged for sampling. The packer is often positioned immediately above the well screen so that only water in the screened area of the well will require purging once the packer is properly inflated.

C.2.4.4.3 Sampling procedure. Recommended sampling procedures are as follows:

- C Prepare the work area outside the well by placing plastic sheeting on the ground to avoid cross-contamination.
- C Determine the amount of water to be removed for purging. Determine the saturated water column in the well using an electronic water level indicator. Calculate the fluid volume in the casing if an inflatable packer is not present in the well. If an inflatable packer is present in the well, refer to construction diagrams of the well to determine the saturated water column below the packer. Make sure that the packer is not within the screened interval.
- C Attach a pressurized air hose to the packer connection (if present) and inflate packer to proper pressurization level, typically 60 to 80 psi. After the packer is inflated, reattach pressurized air hose to the bladder pump connection and purge the well as discussed in Section C.2.4.4.2.
- C Measure the rate of discharge frequently. A bucket of known volume and a stopwatch are commonly used.
- C Purge well until the DO, pH, specific conductance, temperature, and turbidity are each at equilibrium, and begin sampling. Equilibrium is established as follows: ± 10 percent for DO, ± 0.2 pH units, ± 3 percent for specific conductance, ± 1 degree Celsius for temperature, and ± 10 percent for turbidity. (If redox potential is used as an indicator, ± 10 mV should be used as the stabilization criterion.)
- C Ensure that equilibrium is established by making three consecutive readings, where one casing volume is pumped between each reading.
- C Collect VOA samples first following guidelines specified within this appendix.
- C Fill sample bottles of remaining parameters by allowing pump discharge to flow gently down the side of the bottle with minimal entry turbulence. The pump discharge rate should be less than 500 mL/min. Cap each bottle as filled.
- C Preserve the sample as necessary and verify that the pH is sufficient for the criteria.
- C Check that a PTFE liner is present in the cap. Secure the cap tightly.
- C Label the sample with an appropriate label. Be sure to complete the label with all necessary information.

- C Place filled sample containers on ice immediately along with the required trip blank, if analyzing for VOCs.
- C Complete chain-of-custody documents, field logbook, and appropriate field sheet (see Instruction F-1, "Documentation," in Appendix F).
- C Depressurize packer (if present), remove the pump, and close well.

C.2.4.5 Hand pumps. Hand pumps are positive displacement pumping systems designed for developing, purging, and sampling (for some analyses) 5-cm (2-in.) or larger ground water monitoring wells.

C.2.4.5.1 Applicability. Hand pumps do not require an external power source. Units are easily transported. A sustained pumping rate can be achieved. The hand pump could cause cross-contamination if the unit is not thoroughly decontaminated. The hand pump may not be suitable for collecting samples for VOCs because the pump creates a vacuum pressure on the water during operation, which may result in degassing of volatile compounds.

C.2.4.5.2 Method summary and equipment. Hand pumps are readily transportable and can be used to provide sampling in remote areas. Hand operation enables the user to vary the pumping rate to more than 4 gpm at depths exceeding 30 m (100 ft). Hand pumps are typically constructed of offset sizes of PVC piping and check valves. Typically, a small-diameter pipe resides within a larger diameter pipe. The small-diameter pipe is forced up and down and the resulting movement creates a positive displacement.

C.2.4.5.3 Sampling procedure. Recommended sampling procedures are as follows:

- C Prepare the work area outside the well by placing plastic sheeting on the ground to prevent cross-contamination.
- C Determine the saturated water column in the well using an electronic water level indicator. Calculate the fluid volume in the casing and determine the amount of water to be removed for purging.
- C Lower the decontaminated hand pump assembly into the well and begin operating the pump in a steady motion.
- C Measure the rate of discharge frequently. A bucket of known volume and a stopwatch are commonly used.
- C Purge well until the DO, pH, specific conductance, temperature, and turbidity are each at equilibrium, and begin sampling. Equilibrium is established as follows: ± 10 percent for DO, ± 0.2 pH units, ± 3 percent for specific conductance, ± 1 degree Celsius for temperature, and ± 10 percent for turbidity. (If redox potential is used as an indicator, ± 10 mV should be used as the stabilization criterion.)
- C Ensure that equilibrium is established by making three consecutive readings, where one casing volume is pumped between each reading.
- C Collect VOA samples first.

- C Fill sample bottles for remaining parameters by allowing pump discharge to flow gently down the side of the bottle with minimal entry turbulence. The pump discharge rate should be less than 500 mL/min. Cap each bottle as filled.
- C Preserve the sample as necessary and verify that the pH is sufficient for the criteria.
- C Check that a PTFE liner is present in the cap. Secure the cap tightly.
- C Label the sample with an appropriate label. Be sure to complete the label with all necessary information.
- C Place filled sample containers on ice immediately along with the required trip blank, if analyzing for VOCs.
- C Complete chain-of-custody documents, field logbook, and appropriate field sheet (see Instruction F-1, "Documentation," in Appendix F).
- C Remove the pump assembly and decontaminate.
- C Close the well.

C.2.4.6 Centrifugal pump. A centrifugal pump is a type of suction pump used to purge wells.

C.2.4.6.1 Applicability. Advantages of centrifugal pumps include their ability to provide substantial pumping rates and their ready availability. Disadvantages are that they require an external power source and may be difficult to decontaminate between wells. The materials with which these pumps are constructed may frequently be incompatible with certain sample analytes. The centrifugal pump is not suitable for collecting samples for VOC analysis because the pump creates a vacuum pressure on the water during operation, which results in degassing of volatile compounds. These pumps cannot pull water more than 6 m (20 vertical ft).

C.2.4.6.2 Method summary and equipment. Centrifugal pumps are a type of suction pump. An impeller rotating inside the pump chamber discharges water by centrifugal force. The resulting pressure drop in the chamber creates a suction that causes water to enter the intake pipe in the well. Since entrance of water into the intake depends on atmospheric pressure, the height of the intake lift is limited to about 6 m (20 ft) at sea level and less at higher altitudes. Discharge rates from 19 to 151 L per minute (5 to 40 gpm) can be attained and water can be pushed as high as 46 m (150 ft) above the pump. Pumps are typically motorized by a small gasoline engine attached to the pump.

C.2.4.6.3 Sampling procedure. Recommended sampling procedures are as follows:

- C Prepare the work area outside the well by placing plastic sheeting on the ground to avoid cross-contamination.
- C Determine the saturated water column in the well using an electronic water level indicator. Calculate the fluid volume in the casing and determine the amount of water to be removed for purging.
- C Lower decontaminated intake hose into well.
- C Prime pump with distilled water and start pump.

- C Containerize or discharge purge water accordingly.
- C Measure the rate of discharge frequently. A bucket of known volume and a stopwatch are commonly used.
- C Purge well until the DO, pH, specific conductance, temperature, and turbidity are each at equilibrium, and begin sampling. Equilibrium is established as follows: ± 10 percent for DO, ± 0.2 pH units, ± 3 percent for specific conductance, ± 1 degree Celsius for temperature, and ± 10 percent for turbidity. (If redox potential is used as an indicator, ± 10 mV should be used as the stabilization criterion.)
- C Ensure that equilibrium is established by making three consecutive readings, where one casing volume is pumped between each reading.
- C Collect VOA samples first.
- C Fill sample bottles for remaining parameters by allowing pump discharge to flow gently down the side of the bottle with minimal entry turbulence. The pump discharge rate should be less than 500 mL/min. Cap each bottle as filled.
- C Preserve the samples as necessary and verify that the pH is sufficient for the criteria.
- C Check that a PTFE liner is present in the cap. Secure the cap tightly.
- C Label the sample bottle with an appropriate label. Be sure to complete the label with all necessary information.
- C Place filled sample containers on ice immediately, along with the required trip blank, if analyzing for VOCs.
- C Complete chain-of-custody documents, field sheet, and field logbook (see Instruction F-1, "Documentation," in Appendix F).
- C Close the well.

C.2.4.7 Peristaltic pump. Peristaltic pumps operate in a manner similar to that of centrifugal pumps but displace the fluid by mechanical peristalsis (Figure C-3).

C.2.4.7.1 Applicability. An advantage of the peristaltic pump is its design, which isolates the sample from the moving part of the pump and allows for easy decontamination by removal or replacement of the flexible tubing. Tubing can be dedicated to wells to reduce decontamination time. Disadvantages of these pumps include their low pumping rates and their limited height of intake lift (less than 6 m (20 ft)). These pumps also require an outside power source and, like other suction pumps, are not suitable for collecting samples for VOC analysis because of potential degassing effects.

C.2.4.7.2 Method summary and equipment. A flexible sampling tube is mounted around the pump chamber, and rotating rollers compress the tubing, forcing fluid movement ahead (the peristaltic effect) and

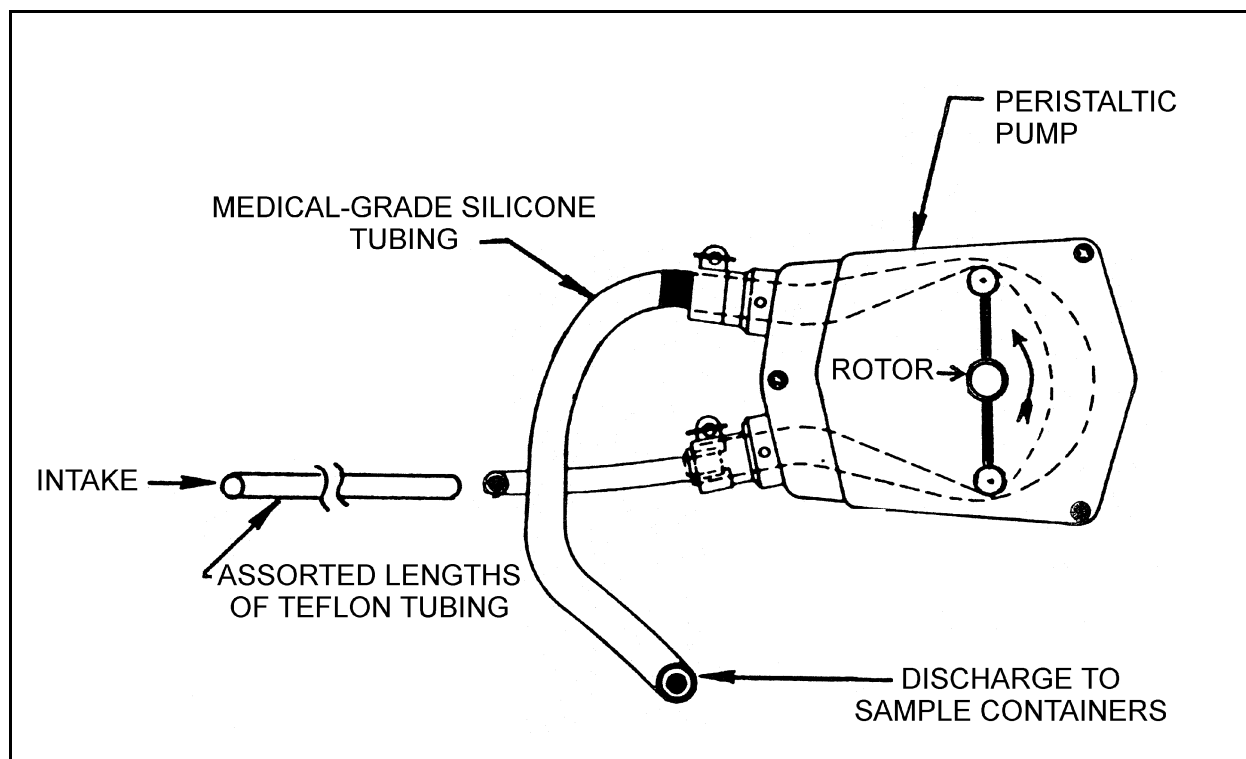


Figure C-3. Peristaltic pump

inducing suction behind each roller (Figure C-3). Peristaltic pumps generally have very low pumping rates suitable only for sampling shallow water tables in small-diameter wells.

C.2.4.7.3 Sampling procedures. Recommended sampling procedures are as follows:

- C Prepare the work area outside the well by placing plastic sheeting on the ground to avoid cross-contamination.
- C Determine the saturated water column in the well using an electronic water level indicator. Calculate the fluid volume in the casing and determine the amount of water to be removed for purging.
- C Install clean medical-grade silicone tubing in the peristaltic pump head and attach the silicone tubing to the glass tubing outlet from the sample bottle.
- C Attach the inlet glass tubing from the sample bottle to the required length of new PTFE suction line and lower to the midpoint of the well screen, if known, or slightly below the existing water level.
- C Purge well until the DO, pH, specific conductance, temperature, and turbidity are each at equilibrium, and begin sampling. Equilibrium is established as follows: ± 10 percent for DO, ± 0.2 pH units, ± 3 percent for specific conductance, ± 1 degree Celsius for temperature, and ± 10 percent for turbidity. (If redox potential is used as an indicator, ± 10 mV should be used as the stabilization criterion.)

- C Ensure that equilibrium is established by making three consecutive readings, where one casing volume is pumped between each reading.
- C Collect VOA samples, if required, with a bailer following guidelines established within this appendix.
- C Fill sample bottles for remaining parameters by allowing pump discharge to flow gently into the bottle with minimal entry turbulence. Pump discharge should be less than 500 mL/min. Cap each bottle as filled.
- C Preserve the samples as necessary and verify that the pH is sufficient for the criteria.
- C Verify that a PTFE liner is present in the cap. Secure the cap tightly.
- C Label the sample bottle with an appropriate label. Be sure to complete the label with all necessary information.
- C Place filled sample containers on ice immediately along with the required trip blank, if analyzing for VOCs.
- C Complete chain-of-custody documents, field sheet, and field logbook (see Instruction F-1, "Documentation," in Appendix F).
- C Allow system to drain, then disassemble. Decontaminate or replace tubing for next sampling.
- C Close the well.

C.2.4.8 Air lift pump. Air lift pumps are usually used for developing or purging recovery wells rather than monitoring wells because of their ease of use and their ability to maintain moderate flow rates. Air lift pumps are not recommended for sampling monitoring wells. Because of the contact with well water and the source gas, the sample could be chemically altered. Depending on the source gas, the pH could be altered, oxidation and degassing of VOCs could occur, and lubricating oils from the air compressor could be introduced.

C.2.4.9 Low-flow (minimal-drawdown) sampling. This method uses any adjustable rate pump that can maintain low flow (typically less than 0.5 L/min) and minimize drawdown. Drawdown ideally should be less than <10 cm (4 in.) during the entire purging and sampling process. Typically used pumps include submersible centrifugal pumps, bladder pumps, and peristaltic pumps. Some pumps are better suited than others, given the well and aquifer constraints. Submersible pumps, for example, have reportedly had difficulty maintaining low flow in shallow 6- to 7.6-m (<20- to 25-ft) aquifers and may overheat under those circumstances. Additional equipment required includes an electronic water level indicator (accurate to 0.3 cm (\pm 0.01 ft)), a multiparameter probe (dissolved oxygen, turbidity, redox potential, pH, temperature, and specific conductivity), and a flow-through cell compatible with the probe.

C.2.4.9.1 Applicability. Low-flow sampling is generally applicable in any instance where a representative nonturbid sample of the aquifer is desired. It is particularly appropriate in low-yield formations where the well would go dry if pumped at higher rates. It is also important to use low-flow techniques in wells that produce samples with high turbidity, which can result in high metals analytical results. Low-flow sampling induces a lower velocity through the screen, which entrains fewer particulates.

Another important advantage is that less purge water is produced, significantly decreasing the costs for handling and disposing of Investigation Derived Wastes (IDW). To implement low-flow sampling appropriately, the water level in the well being sampled needs to be monitored continuously, and the actual flow rate must be measured and adjusted to maintain drawdown in the well to less than 10 cm (4 in.).

C.2.4.9.2 Method summary and equipment. The pump must also be inserted into the well in a way that minimizes the disturbance of any sediments within the well casing, particularly those in the bottom of the well. In no circumstances should the water level probes or pumps be allowed to hit the bottom of the well before or during sampling. If possible the point where water enters the pump should be at least 0.6-0.9 m (2-3 ft) above the bottom of the well. The pump should be turned on at the lowest setting possible, and that setting should be raised gradually until a continuous flow is achieved from the discharge tube. During this time the water level needs to be monitored and the flow rate adjusted to maintain the drawdown to less than 10 cm (4 in.) if possible. In no circumstances should the water level be allowed to break suction in the pump. The pump is to be turned off when that happens and turned on again when sufficient recharge has occurred. If there is a stagnant column of water in the casing above the screen, it is essential that the water level not be allowed to come down to the screen. If this should appear imminent, the pump should be shut off and the well allowed to recover before purging continues. There are wells that even at pumping rates of 100-200 mL/min will not be able to recharge sufficiently. In those circumstances the sampling team needs to reassess the sampling goals for that location and determine whether there are other more appropriate ways to obtain a representative sample. To successfully monitor the representativeness of the water sample the most sensitive parameters (DO, redox potential, and turbidity) must be measured along with the traditional parameters of pH, temperature, and conductivity. To accurately measure DO and redox requires the use of a flow-through cell, which allows water to be pumped directly from the well and contact the probe(s) without contacting the atmosphere. There is no acceptable alternative to the flow-through cell for accurate measurement of DO and redox. Readings should be taken of all parameters every 3-5 minutes. If after three casing volumes have been removed from the well the turbidity is not <5 , this should be noted in the log and the samples should be collected.

C.2.4.9.3 Sampling procedures. Recommended sampling procedures are as follows:

- C Prepare the work area outside the well by placing plastic sheeting on the ground to avoid cross-contamination.
- C Determine the saturated water column in the well using an electronic water level indicator. NOTE: Do not tag the bottom of the well since the total depth should be on the well construction diagram. Anything that hits the bottom of the well risks disturbing any fines that are there, and they may subsequently be entrained in the sample. Calculate the fluid volume in the casing and determine the amount of water to be removed for purging.
- C Connect the pump tubing to the flow-through cell and connect the multiparameter probe to the cell.
- C Purge well until the DO, pH, specific conductance, temperature, and turbidity are each at equilibrium, and begin sampling. Equilibrium is established as follows: ± 10 percent for DO, ± 0.2 pH units, ± 3 percent for specific conductance, ± 1 degree Celsius for temperature, and ± 10 percent for turbidity. (If redox potential is used as an indicator, ± 10 mV should be used as the stabilization criterion.)
- C Establish equilibrium by making three consecutive readings, with 3 to 5 minutes between each reading.

- C Detach the tubing from the flow-through cell and collect VOA samples first.
- C Collect VOA samples, if required, following guidelines established within this appendix. Fill sample bottles for remaining parameters by allowing pump discharge to flow gently into the bottle with minimal entry turbulence. Pump discharge should be less than 500 mL/min. Cap each bottle as filled.
- C Preserve the samples as necessary and verify that the pH is sufficient for the criteria.
- C Verify that a PTFE liner is present in the cap. Secure the cap tightly.
- C Label the sample bottle with an appropriate label. Be sure to complete the label with all necessary information.
- C Place filled sample containers on ice immediately along with the required trip blank, if analyzing for VOCs.
- C Complete chain-of-custody documents, field sheet, and field logbook (see Instruction F-1, "Documentation," in Appendix F).
- C Allow system to drain, then disassemble. Decontaminate or replace tubing for next sampling.
- C Close the well.

C.2.4.10 Emerging and innovative sampling procedures. All of the standard samplers described in this appendix for the sampling of ground water disrupt equilibrium during the sampling event to some degree. This may lead to obtaining a sample that is not representative of the actual environmental conditions or contaminant concentrations. New sampling devices and sampling procedures have been designed to minimize the disturbance to the medium during sampling, circumvent the need to purge the well, and minimize the influence on and any bias to the results that this disturbance, the stagnant water above or below the well screen, or fines contained within the monitoring well may impose. Recent studies have shown the application of diffusion samplers to the acquisition of samples for VOCs, a chemical parameter susceptible to loss from the disturbance imposed by purging and sampling (Vroblesky and Hyde 1997). The diffusion samplers are constructed of polyethylene bags containing deionized water that is strategically hung within the screened interval of the monitoring well and left for a predetermined time (e.g., 11-54 days). Polyethylene is shown to allow the transmission of various halogenated and aromatic VOCs, and is used as a semipermeable membrane to allow the diffusion of VOCs from the ground water to the deionized water contained within the bags. The sampler may also be designed to have multiple discrete cells that are vertically separated. This configuration allows the monitoring of VOC concentrations as they pertain to different depth intervals. After the sampling period, the diffusion samplers are collected from the wells by the attached strings, and the water is gently poured from the sampler into 40-mL VOA vials through the PTFE stopcock. Samples are then processed in the same manner as other sampling techniques. The diffusion samplers are commercially available; easy to deploy, retrieve, and sample; and an inexpensive alternative for the acquisition of VOC samples in ground water monitoring wells or other water bodies.

C.2.4.11 Decontamination procedures. All equipment that will enter the well must be decontaminated before entry. The inside surface of pumps and tubing apparatus must be decontaminated by drawing the decontamination solution through the equipment. Field measurement equipment such as water level indicators should be cleaned as described in Instruction E-6, Appendix E. If the sampling equipment is being

prepared for later use, it should be wrapped in cleaned foil. The sampling equipment should remain wrapped in this manner until immediately before use. Additional sampling devices may be needed onsite to ensure an adequate drying time. The requirement for dedicated equipment should apply to all bailers used for collecting samples. Bailers, other sampling equipment, and sample bottles must be physically separated from generators during transport and storage. Decontamination procedures for field equipment are discussed in Instruction E-6 (Appendix E).

C.2.4.12 Field control sample requirements. Field control samples are collected by the sampling team to determine whether the data are of suitable quality. They include blanks, replicates, and/or background (upgradient) samples. Quality Assurance (QA) samples are replicates sent to a referee (QA) laboratory and analyzed to evaluate the contractor's laboratory performance. Quality Control (QC) samples are blind replicates collected by the sampling team for analysis by the primary laboratory. A detailed discussion of field control samples is contained in Instruction G-2 (Appendix G).

C.2.4.13 Documentation requirements. Bound field logbooks should be used for the maintenance of field records. Record all aspects of the site setup and sample collection and handling as outlined previously and in Instruction F-1 of Appendix F.

C.3 Surface Water Sampling

C.3.1 Scope and application.

C.3.1.1 This instruction presents guidelines for collecting representative samples from surface water bodies. Surface water bodies can be classified into two primary types: flowing and standing. Flowing bodies include industrial effluent, municipal wastewater, rivers, sewers, leachate seeps, streams, or any other lotic water body. Standing bodies include lagoons, ponds, nonaqueous (e.g., surface impoundments), lakes, or any other lentic water body. Surface water samples can be collected from various depths of the water bodies using some of the techniques described herein. Instructions for sampling surface water bodies using the following techniques are included: hand-held bottle, dipper, pond sampler, peristaltic pump, Kemmerer sampler, weighted bottle, and Bacon bomb sampler.

C.3.1.2 Storm water runoff sampling is another type of surface water sampling done to acquire the qualitative and quantitative data necessary to complete National Pollution Discharge Elimination System (NPDES) storm water permits, and to determine the effectiveness of storm water management plans. NPDES permits are issued by the state for permanent areas that due to their purpose or mission (e.g., petroleum, oils, and lubricants (POL), runway, hazardous waste (HW) storage area) may pose a potential environmental risk from storm water runoff through the area. The permit should define the appropriate sampling locations and testing requirements based on the location and types of contaminant sources present and site topography. Sampling of storm water runoff is based on simple standard sampling techniques to acquire representative grab and composite samples from key runoff locations to monitor for visual properties and analytical chemistry parameters as defined by the NPDES permit. Further details on storm water runoff sampling requirements may be found in 40 CFR 122.21(g)(7), 40 CFR 136, and EPA/833/B-92/001.

C.3.2 Sampling strategies. Sampling strategies are developed by the project team to satisfy project-specific data needs that are identified in the HTRW technical planning process. The sampling strategy developed for a particular site will influence several project decisions, including but not limited to sampling locations, types of samples, sampling frequency, and sampling and analytical protocols. For instance, ecological risk assessment may require the need for colocated surface water and sediment samples. Sampling strategies may be significantly influenced by such factors as physical site constraints, safety, and cost, to name a few. The technical planning process that results in the development of the sampling strategy is critical because of the difficulty in acquiring representative surface water samples, the reduction of contaminant action levels, and the problems associated with trace level cross-contamination. Successful investigations of hazardous waste sites are highly dependent on an effective sampling scheme. Development of a sampling scheme to characterize a hazardous waste site should follow the fundamentals of the scientific approach. A successful sampling scheme requires a logical design to allow an evaluation of potential contaminants in relation to background conditions, vertical extent, horizontal extent, and mobility in various media. Regulations covering storm water runoff sampling require that it be performed during a qualifying storm event. The following criteria must be met for the storm event to qualify and the resulting data to be considered a valid data record: the storm event must be preceded by 72 hours of dry weather (rainfall <2.5 cm (<0.1 in.)), the variance in the duration and total rainfall of the storm event may not exceed 50 percent of the average storm event, the storm must produce greater than 2.5 cm (0.1 in.) of rain, and the storm must produce runoff.

C.3.2.1 Sampling locations. Sampling at hazardous waste sites is usually conducted in an attempt to identify contamination and to define its extent and variability. With such an objective, it is most logical to choose sample locations that will yield the most information about site conditions. However, other factors such as accessibility, sampling equipment requirements, and demands on the sampling team need to be considered when selecting locations. When a site is evaluated, sampling can be conducted by random, systematic, or biased sampling. Biased samples are those collected at locations that were chosen based on

historical information, knowledge about the behavior of the contaminants, and/or knowledge about the effects of the physical system on the fate of the contaminant. Random sampling depends on the theory of random chance probabilities to choose the most representative sample. Often biased and random sampling techniques can be used together to address an entire site thoroughly. Some samples may be biased to potentially contaminated areas or potentially impacted areas (e.g., downstream from discharge pipe). In areas less likely to be contaminated or areas with little available background information, random samples may be used to allow adequate assessment of the entire site. Due to the nature of the media, locations for surface water samples are restricted to locations within the water body under evaluation. However, variations of those within the water body may include depth, horizontal location, and time. Storm water runoff sampling locations are defined within the NPDES permit based on the mission and purpose of the evaluated areas and the site topography. Each sample location is defined by the facility name and outfall number.

C.3.2.2 Types of samples. The type of sample should be designated when selecting a sampling method. Surface water samples may be discrete (grab) or composite samples. A discrete (grab) sample is defined as a discrete aliquot representative of a specific location at a given point in time. The sample is collected at one particular point in the sample matrix. The representativeness of such samples is defined by the nature of the materials being sampled. In general, as sources vary over time and distance, the representativeness of grab samples will decrease. Composites are samples composed of two or more specific aliquots (discrete samples) collected at various sampling locations and/or different points in time. Analysis of this type of sample produces an average value and can, in certain instances, be used as an alternative to analyzing a number of individual grab samples and calculating an average value. It should be noted, however, that compositing can mask the presence of contaminants by diluting isolated concentrations of analytes that may be present in the environmental matrix. Regulations covering storm water runoff sampling require that both grab and flow-weighted composite samples be collected. Grab storm water samples are discrete samples, normally collected within the first 30 minutes after the onset of runoff from the storm event or as soon as practicable, but no later than within the first 60 minutes of storm water runoff discharge. To comply with 40 CFR 136, grab sampling techniques are required for several potential analytical chemistry parameters (e.g., pH, temperature, VOCs, oil and grease, fecal coliform, fecal streptococcus, cyanide, total phenols, and residual chlorine). Flow-weighted composite samples are taken during the first 3 hours (or an entire event if less than 3 hours in length) of the storm event. It is a mixed sample from one location, combining discrete samples at specified time intervals in specific volumes that are proportional to the runoff flow. Details on the procedures for measuring or estimating rainfall and runoff flow rates should be referenced from EPA/833/B-92/001.

C.3.2.3 Suggested samplers. Each sampling technique presents various disadvantages and advantages for its application. For example, desired depth, tidal influences, sample disturbance, sample volume, chemical/physical reactivity between potential contaminants and sampling tool materials, and ease of decontamination vary from technique to technique. The following sections discuss the advantages and disadvantages of each sampling technique.

C.3.2.4 Sample frequency. Determination of the number of samples needed to characterize a site depends upon sampling objectives and site-specific conditions. For example, if the objective of the event is to determine whether the site is contaminated, a limited number of samples from properly chosen locations will yield useful information. If, however, the site is known to be contaminated and delineation of the contamination is the objective, a greater number of samples may be needed. In many cases, statistical considerations can be helpful in determining sampling strategy. It may also be necessary to strategically plan the timing of sampling. For example, industrial discharges may be more likely during working hours. Storm water runoff sampling frequency requirements are defined within the facility's NPDES permit.

C.3.3 Sample preservation and handling. Many of the chemical constituents and physicochemical parameters that are to be measured or evaluated in monitoring programs are not chemically stable; therefore, sample preservation is required. Appropriate preservation techniques for various parameters are specified in Appendix B. In addition, sample containers that should be used for each constituent or common set of parameters are specified in Appendix B. These preservation methods and sample containers are based on EPA/SW-846. Procedures and techniques for transporting the samples to the offsite laboratory are discussed in Instruction F-2, "Packaging and Shipping Procedures," in Appendix F. Improper sample handling may alter the analytical results of the sample, causing the results to be invalid. Samples should be transferred in the field from the sampling equipment directly into the container that is required for that analysis or set of compatible parameters and in sufficient volumes, including number of sample containers, to allow appropriate analyses. The sample should then be preserved in the field as specified in Appendix B. Because of the low analytical detection limits that are required for assessment of ecological risk and other data uses, care must be taken when collecting the sample to avoid the loss of any contaminants. The samples for volatile analysis should be carefully transferred directly from the sample collection device to the sample container in order to minimize contaminant loss through agitation/ volatilization or adherence to another container. Samples should be collected in the order listed in Section C.3.3.1. When more than one container is required per parameter, the sample should be split equally among all containers until they are filled. Containers used to collect samples for organic analyses should not be prerinsed with water because of the possibility of preservation loss or the loss/gain of contaminants that may taint the analytical results.

C.3.3.1 Sample containers. When metals are the analytes of interest, HDPE containers with PTFE-lined polypropylene caps should be used. When organics are the analytes of interest, glass bottles with PTFE-lined caps should be used. Refer to Appendix B or the specific analytical method to designate an acceptable container. Containers should be cleaned based on the analyte of interest. Instruction E-6, "Decontamination Procedures," (Appendix E) contains additional information on appropriate glassware cleaning protocols. If precleaned bottles are used, the cleanliness of each lot of precleaned bottles should be verified by the container supplier or in the laboratory and appropriate paperwork (i.e., certificates) retained with other field documentation. Refer to Appendix B for information on the required size, number, and type of sample containers. Samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. A preferred collection order for some common parameters follows:

- VOA
- POC
- POX
- TOX
- TOC
- Extractable organics
- Total metals
- Dissolved metals
- Phenols
- Cyanide
- Sulfate and chloride

- Turbidity
- Nitrate and ammonia
- Radionuclides

C.3.3.2 Sample preservation. Methods of sample preservation are relatively limited and are generally intended to retard biological action and hydrolysis and to reduce sorption effects. Preservation methods are generally limited to pH control, chemical addition, refrigeration, and protection from light. Prepreserved sample containers are not recommended. Because of the potential loss of preservative if field errors occur and because different amounts of preservative may be necessary to bring the sample to the required pH, it is recommended to add the preservative to the container in the field and verify that the pH of the sample has been achieved. This information should be documented within field logbooks. The sampler should refer to Appendix B or the specific preservation method in EPA/SW-846 for the appropriate preservation technique.

C.3.3.3 Special handling for VOA samples. Water samples to be analyzed for purgeable organic compounds should be stored in 40-mL vials with septum inserts and screw caps. The septum should be placed on the sample vial so that the PTFE side is in contact with the sample. The 40-mL vials should be completely filled to prevent volatilization, and extreme caution should be exercised when filling a vial to avoid any turbulence that could also produce volatilization. The sample should be carefully poured down the side of the vial to minimize turbulence. As a rule, it is best to gently pour the last few drops into the vial so that surface tension holds the water in a convex meniscus. The septum is then applied and some overflow is lost, but air space in the bottle is eliminated. After the bottle is capped, it should be turned over and tapped to check for bubbles. If any bubbles are present, the procedure must be repeated. Care should be taken to ensure that no loss of preservative occurs, if applicable.

C.3.3.4 Special precautions for trace contaminant sampling. Contaminants can be detected in the parts per billion and/or parts per trillion ranges. Therefore, extreme care must be taken to prevent cross-contamination of these samples. The following general precautions should be taken when sampling:

- A clean pair of new disposable gloves should be worn each time a different location is sampled, and gloves should be donned immediately prior to sampling.
- To prevent cross-contamination between samples, it is suggested that the multiple vials from each sampling location be sealed in separate smaller plastic bags when the sampled medium is suspected of containing high concentrations of volatile organics.
- Sample containers filled with source or waste samples or samples suspected of containing high concentrations of contaminants should be placed in separate plastic bags immediately after collecting and preserving, and activated carbon should be included in the bags to prevent cross-contamination.
- If possible, background samples and source samples should be collected by different field teams. If different field teams cannot be used, all background samples should be collected first and placed in separate ice chests or shipping containers. Samples of waste or highly contaminated samples should never be placed in the same ice chest as environmental samples. It is good practice to enclose waste or highly contaminated samples in a plastic bag before placing them in ice chests. Ice chests or shipping containers for source samples or samples suspected to contain high concentrations of contaminants should be lined with new, clean, plastic bags.

- If possible, one member of the field team should take all the notes and fill out sample tags, field sheets, etc., while the other members collect all of the samples.
- Sample collection activities should proceed progressively from the suspected least contaminated area to the suspected most contaminated area.
- Field personnel should use equipment constructed of PTFE, stainless steel, or glass that has been properly precleaned. PTFE or glass is preferred for collecting samples where trace metals are of concern.
- Adequate field control samples should be collected.

C.3.4 Sampling methods. Sampling instructions for the most common techniques for collecting surface water samples are presented in this section. Additional guidance on surface water sampling methods may be found in EM 200-1-2 and EPA/600/2-80/018. Prior to sample collection, water body characteristics (size, depth, flow) should be recorded in the field logbook. Sampling should proceed from downstream locations to upstream locations so that disturbance related to sampling does not affect the samples collected on the upstream side. In addition, if sediment samples are to be collected at the same locations as water samples, the water samples must be collected first. If the project requirements make it necessary to distinguish the concentration of metals in solution from the concentration of metals associated with solids, filtration of the surface water will be required. Filtration techniques are discussed in Instruction E-1 (Appendix E) of this manual. The factors that will contribute to the selection of a surface water sampler include the width, depth, and flow of the surface water body location being sampled, and whether the sample will be collected from the shore or a vessel. For flowing liquids an additional concern must be addressed. Tidal influence should be determined, and its influence on sample collection should be detailed in the sampling plan. At a minimum, the stage of the tide at the time of sample collection should be recorded. Consideration should be given to sampling at varied tidal stages. Samplers may encounter situations where rate of flow affects their ability to collect a sample. For fast-flowing rivers and streams, it may be nearly impossible to collect a midchannel sample at a specific point. Low-flowing streams and leachate seeps present the opposite problem. In these cases, the sampler should attempt to find a location where flow is obstructed and a pool is created. If this is not possible, the only way to obtain a sample may be to dig into the sediment with a decontaminated trowel to create a pooled area where the liquid will accumulate. However, this method is not recommended since the sample is likely to be highly turbid. If the banks are not sloping, sampling personnel may be able to collect the liquid directly into the sample bottle from the edge of the water body. In some instances where the liquid to be sampled cannot be reached, a pond sampler, by virtue of its extension capabilities, may be necessary. In these cases, the pond sampler should be assembled to ensure that sampling personnel are not in danger of falling into the water body being sampled. In cases where access is restricted, or data objectives require a sample taken from the middle of the water body, a boat, barge, or other stable working platform may be necessary. For a stream, channel, or river, the sample should be collected at middepth. For standing liquid, the sample should be collected just below the surface or at middepth. Specific sampling strategies may be altered depending on the contaminants of concern. For instance, when sampling for hydrocarbons or other light nonaqueous phase liquids, it may be better to sample at the surface. Once the sample is obtained, it should be transferred directly into the sample bottle. The sampling device should be decontaminated before the next sample is taken. If sampling below the water surface is required, some of the samplers discussed in the following sections will allow collection of discrete representative liquid samples at various depths. Proper use of the sampling device chosen includes slow lowering and retrieval of the sample, immediate transfer of the liquid into the sampling container, and notation in the logbook of the depth at which the sample was collected.

C.3.4.1 Hand-held bottle.

C.3.4.1.1 Applicability. Filling the sample containers directly is advantageous when the sample might be significantly altered during transfer from a collection vessel into another container. This would affect samples being collected for VOC analysis. The hand-held bottle is not applicable for samples required at depth.

C.3.4.1.2 Method summary and equipment. Samples from shallow depths can be readily collected by merely submerging the sample containers.

C.3.4.1.3 Sampling procedure. The recommended sampling procedure follows:

- C Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination. If access to sampling location is restricted, locate a boat, barge, or other stable working platform adjacent to the area to be sampled.
- C Submerge the sample container with the cap in place with minimal surface disturbance so that the open end is pointing upstream.
- C Allow the device to fill slowly and continuously using the cap to regulate the speed of water entering the bottle.
- C Retrieve the sample container from the surface water with minimal disturbance.
- C Preserve the sample as necessary and verify that the pH is sufficient for the criteria.
- C Verify that a PTFE liner is present in the cap. Secure the cap tightly.
- C Label the sample bottle with an appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Place filled sample containers on ice immediately along with the required trip blank, if analyzing for VOCs.
- C Record the information in the field logbook and complete the chain-of-custody form and field sheets (See Instruction F-1, "Documentation," in Appendix F).

C.3.4.2 Dippers and pond samplers. Method Reference: ASTM D 5358.

C.3.4.2.1 Applicability. Dippers and pond samplers prevent unnecessary contamination of the outer surface of the sample bottle that would otherwise result from direct immersion in the source. Dippers and pond samplers can be either reused or discarded. Discarding the samplers would eliminate the need for decontamination. With the pond sampler, samples can be obtained at distances as far as 3 m (10 ft) from the edge of the source, preventing the technician from having to contact the source physically. The tubular handle may bow when sampling very viscous liquids if sampling is not done slowly. Dippers and pond samplers perform similar functions, except that the length of the dipper is smaller.

C.3.4.2.2 Method summary and equipment. The pond sampler consists of an adjustable clamp attached to the end of a two- or three-piece telescoping aluminum or fiberglass pole that serves as the handle. The clamp is used to secure a sampling beaker (Figure C-4).

C.3.4.2.3 Sampling procedure. The recommended sampling procedure follows:

- C Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination. If access to sampling location is restricted, locate a boat, barge, or other stable working platform adjacent to the area to be sampled.

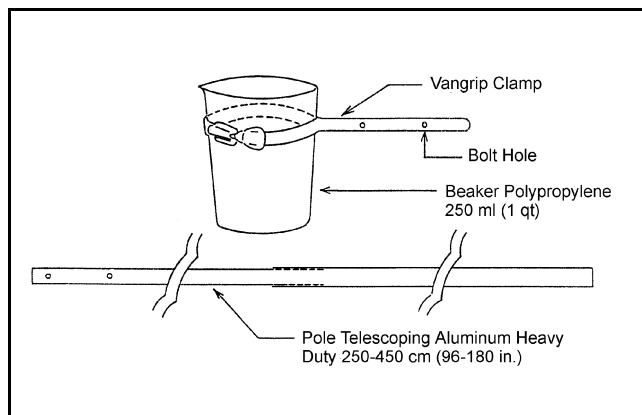


Figure C-4. Pond sampler

- C Assemble the dipper or pond sampler. If appropriate, make sure that the sample container and the bolts and nuts that secure the clamp to the pole are tightened properly.
- C Collect samples by slowly submerging the precleaned dipper or pond sampler with minimal surface disturbance. Make sure that the open end is pointed upstream.
- C Retrieve the dipper or pond sampler from the surface water with minimal disturbance.
- C Remove the cap from the sample bottle and slightly tilt the mouth of the bottle below the edge of the dipper/sampler.
- C Empty the sampler slowly, allowing the sample stream to flow gently down the side of the bottle with minimal entry turbulence.
- C Continue delivery of the sample until the bottle is filled.
- C Preserve the sample as necessary and verify that the pH is sufficient for the criteria.
- C Check that a PTFE liner is present in the cap. Secure the cap tightly.
- C Label the sample bottle with an appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Place filled sample containers on ice immediately, along with the required trip blank, if analyzing for VOCs.
- C Record the information in the field logbook and complete the chain-of-custody documents and field sheets (See Instruction F-1, "Documentation," in Appendix F).
- C Properly clean and decontaminate the equipment prior to reuse or storage.

C.3.4.3 Peristaltic pump. Method Reference: EPA/600/4-84/076

C.3.4.3.1 Applicability. An advantage of the peristaltic pump is its design, which isolates the sample from the moving part of the pump and allows for easy decontamination by removal or replacement of the

flexible tubing. This method can both extend the lateral reach of the sampler and allow sampling from depths below the water surface. Disadvantages of these pumps include their low pumping rates and their limited height of intake lift (less than 6 m (20 ft)). These pumps also require an outside power source and, like other suction pumps, are not suitable for collecting samples for VOC analysis because of potential degassing effects.

C.3.4.3.2 Method summary and equipment. Peristaltic pumps displace fluid by mechanical peristalsis. A flexible sampling tube is mounted around the pump chamber, and rotating rollers compress the tubing, forcing fluid movement ahead (the peristaltic effect) and inducing suction behind each roller (Figure C-3).

C.3.4.3.3 Sampling procedure. The recommended sampling procedure follows:

- C Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination. If access to sampling location is restricted, locate a boat, barge, or other stable working platform adjacent to the area to be sampled.
- C Install clean, medical-grade silicone tubing in the pump head, as instructed by the manufacturer. Attach the silicone tubing to the glass tubing outlet from the sample bottle. If the sampling device is not constructed as shown in Figure C-3 and the sample bottle is filled directly from the discharge line of the peristaltic pump, the sample will be in direct contact with the intake tubing, the pump head, and the discharge tubing prior to release to the sample container. In this situation, PTFE tubing must be used for the discharge line to avoid cross-contamination of the samples from contaminant leaching that would occur from other “less inert” tubing.
- C Select the length of suction intake tubing necessary to reach the required sample depth and attach it to the intake side of the sample bottle. Heavy-wall PTFE or a diameter equal to the required pump tubing will suit most applications. (A heavier wall will allow for a slightly greater lateral reach.)
- C If possible, allow several liters of sample to pass through the system before actual sample collection. Collect this purge volume and return it to the source after the sample aliquot has been withdrawn.
- C Collect VOA samples, if required, with an alternative sampling device following guidelines established in this appendix.
- C Fill the necessary sample bottles by allowing pump discharge to flow gently down the side of bottle with minimal entry turbulence. Cap each bottle as filled.
- C Preserve the sample as necessary and verify that the pH is sufficient for the criteria.
- C Check that a PTFE liner is present in the cap. Secure the cap tightly.
- C Label the sample bottle with an appropriate label. Be sure to complete the label with all necessary information.
- C Place filled sample containers on ice immediately, along with the required trip blank, if analyzing for VOCs.

- C Record the information in the field logbook and complete the chain-of-custody documents and field sheets (See Instruction F-1, "Documentation," in Appendix F).
- C Allow system to drain, then disassemble it. Decontaminate tubing if necessary; otherwise discard appropriately.

C.3.4.4 Kemmerer sampler. Method References: ASTM D 4136 and EPA/540/P-91/005, Standard Operating Procedure (SOP) #2013, "Surface Water Sampling."

C.3.4.4.1 Applicability. The Kemmerer sampler is a practical method for collecting discrete, at-depth samples where the collection depth exceeds the lift capacity of pumps. The use of the Kemmerer sampler is limited, however, because it is typically constructed of brass.

C.3.4.4.2 Method summary and equipment. The Kemmerer sampler is a messenger-activated water sampling device that is used to sample water from a specific depth (Figure C-5). In the open position, water flows easily through the device. Once the device is lowered to the desired depth, a messenger is dropped down the sample line tripping the release mechanism and closing the container. In the closed position, the bottle is sealed at the top and bottom, isolating the sample during retrieval.

C.3.4.4.3 Sampling procedure. The recommended sampling procedure follows:

- C Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination. If access to sampling location is restricted, locate a boat, barge, or other stable working platform adjacent to the area to be sampled.
- C Inspect Kemmerer sampler to ensure that sample drain valve is closed (if equipped).
- C Measure and mark sampler line at desired sampling depth.
- C Open bottle by lifting top stopper-trip head assembly.
- C Gradually lower bottle until desired sample depth is reached.

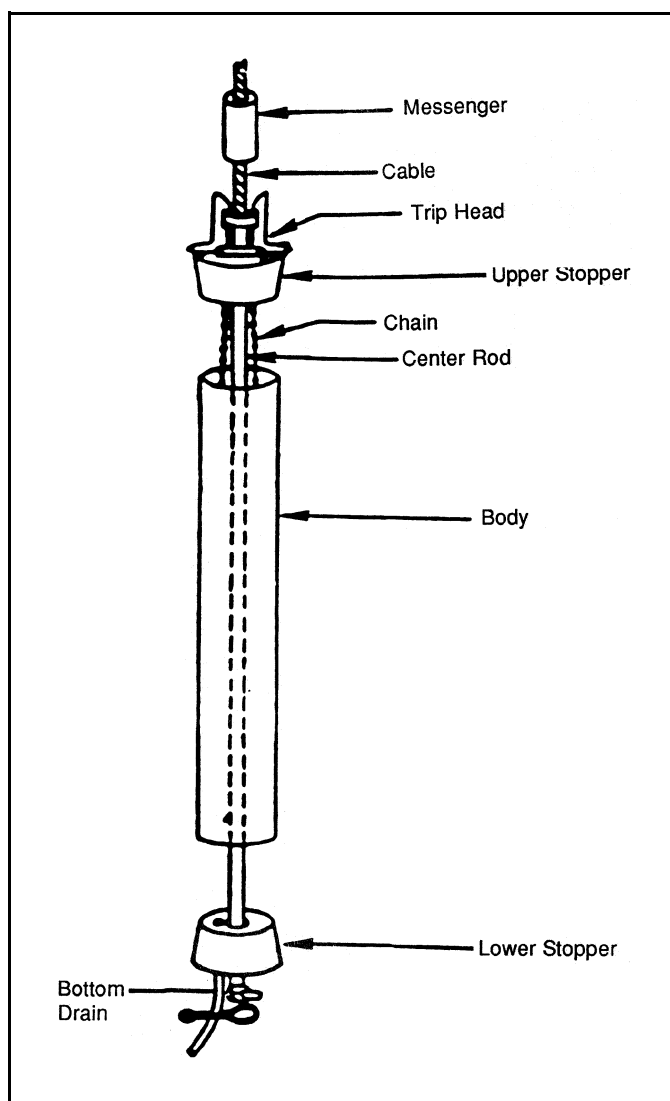


Figure C-5. Kemmerer sampler

- C Place messenger on sample line and release.
- C Retrieve sampler; hold sampler by center stem to prevent accidental opening of bottom stopper.
- C Rinse or wipe off exterior of sampler body.
- C Recover sample by grasping lower stopper and sampler body with one hand (gloved), and transfer sample by either lifting top stopper with other hand and carefully pouring contents into sample bottles or holding drain valve (if present) over sample bottle and opening valve.
- C Allow sample to flow slowly down the side of the sample bottle with minimal disturbance.
- C Preserve the sample as necessary and verify that the pH is sufficient for the criteria.
- C Check that a PTFE liner is present in the cap. Secure the cap tightly.
- C Label the sample bottle with an appropriate label. Be sure to complete the label with all necessary information.
- C Place filled sample containers on ice immediately, along with the required trip blank, if analyzing for VOCs.
- C Record the information in the field logbook and complete all chain-of-custody records and field sheets (See Instruction F-1, "Documentation," in Appendix F).
- C Decontaminate sampler.

C.3.4.5 Weighted bottle. Method References: ASTM D 4057 and ASTM E 300.

C.3.4.5.1 Applicability. The weighted bottle can be used to obtain samples from a specific depth. The glass construction of the sampler can make the use of this sampler more desirable than the Kemmerer in some sampling situations.

C.3.4.5.2 Method summary and equipment. The weighted bottle can be used for collecting representative samples from a specific depth. The sampler consists of a glass bottle, a weighted sinker, a bottle stopper, and a line that is used to lower and raise the sampler during sampling. Once the sampler is lowered to the desired sampling depth, the stopper is opened, and the bottle is filled and retrieved to the surface.

C.3.4.5.3 Sampling procedure. The recommended sampling procedure follows:

- C Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross- contamination. If access to sampling location is restricted, locate a boat, barge, or other stable working platform adjacent to the area to be sampled.

C Assemble the weighted bottle sampler as shown in Figure C-6.

C Measure and mark the sampler line at the desired sampling depth.

C Lower the sampling device to the predetermined depth.

C When the sampler is at the required depth, pull out the bottle stopper with a sharp jerk of the sampler line and allow the bottle to fill completely. (This is usually evidenced by the cessation of air bubbles.)

C Retrieve the sampler.

C Rinse or wipe off the exterior of the sampler body.

C Allow sample to flow slowly down the side of sample bottle with minimal disturbance.

C Preserve the sample as necessary and verify that the pH is sufficient for the criteria.

C Check that a PTFE liner is present in the cap. Secure the cap tightly.

C Label the sample bottle with an appropriate label. Be sure to complete the label with all necessary information.

C Place filled sample containers on ice immediately, along with the required trip blank, if analyzing for VOCs.

C Record the information in the field logbook and complete all chain-of-custody records and field sheets (see Instruction F-1, "Documentation," in Appendix F).

C Decontaminate sampler.

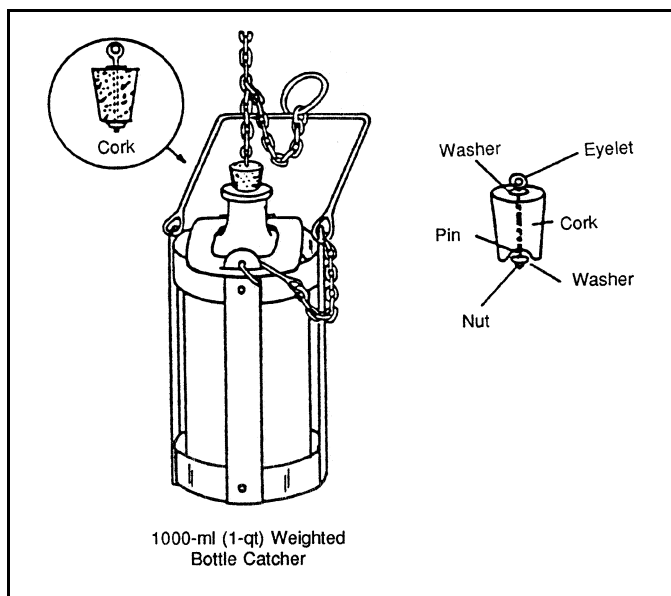


Figure C-6. Weighted bottle

C.3.4.6 Bacon bomb sampler. Method Reference: EPA/540/P-91/005, SOP #2013.

C.3.4.6.1 Applicability. The Bacon bomb sampler is a widely used, commercially available sampler, designed for sampling petroleum products and viscous liquids (Figure C-7). It is very useful for sampling larger storage tanks because the internal collection chamber is not exposed to a product until the sampler is triggered. It is useful in collecting samples at various vertical locations. Like the weighted bottle sampler, the Bacon sampler remains unopened until it reaches the desired sampling depth. The Bacon sampler is difficult to decontaminate, and it is difficult to transfer the sample into the sample bottles. The possibility of aerating the sample exists if the sampler does not completely fill with water and air is entrapped in the sampler during retrieval.

C.3.4.6.2 Method summary and equipment. The Bacon bomb sampler is constructed of brass or stainless steel and is available in two sizes: 37 mm (1.5 in.) or 87 mm (3.5 in.) in diameter. Samplers range in volume from 0.1 L to 1 L (4 oz to 32 oz). The Bacon bomb sampler is equipped with a trigger that is spring loaded. When opened, the trigger allows liquid to enter the collection chamber. When the trigger is released, liquid is prevented from flowing into or out of the collection chamber.

C.3.4.6.3 Sampling procedure. The recommended sampling procedure follows:

- C Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination. If access to sampling location is restricted, locate a boat, barge, or other stable working platform adjacent to the area to be sampled.
- C Measure and mark the sampler line at the desired sampling depth.
- C Lower the Bacon bomb sampler carefully to the desired sampling depth, allowing the line for the trigger to remain slack at all times. When the desired depth is reached, pull the trigger line taut.

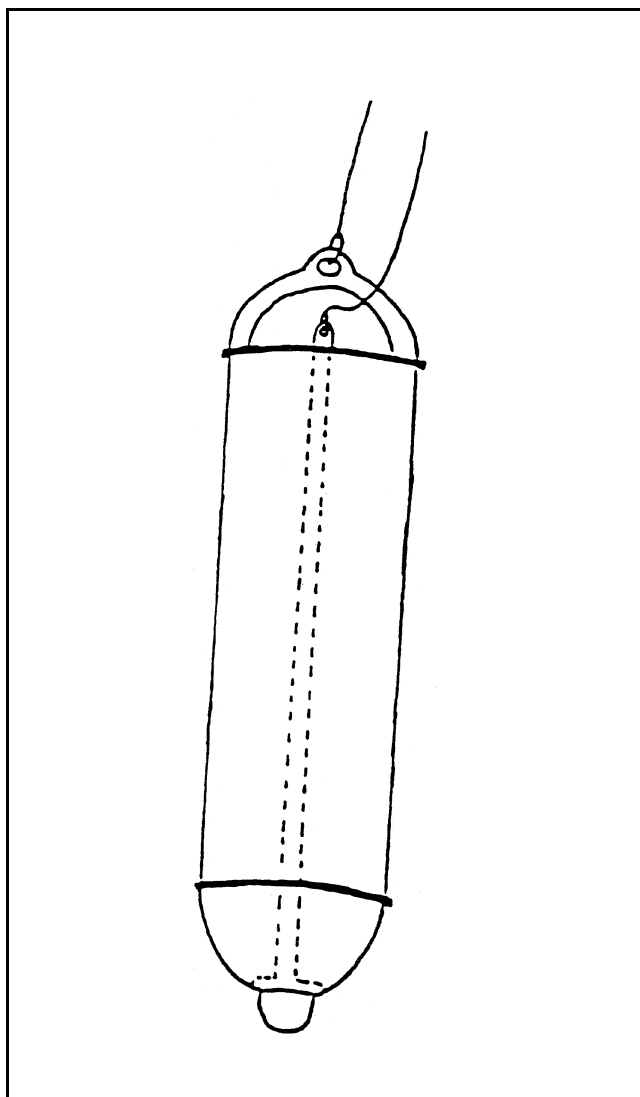


Figure C-7. Bacon bomb sampler

- C Release the trigger line and retrieve the sampler.
- C Transfer the sample to the sample bottles by pulling on the trigger. Allow the sample to flow down the side of the sample bottle with minimal disturbance.
- C Preserve the sample as necessary and verify that the pH is sufficient for the criteria.
- C Check that a PTFE liner is present in the cap. Secure the cap tightly.
- C Label the sample bottle with an appropriate label. Be sure to complete the label with all necessary information.
- C Place filled sample containers on ice immediately, along with the required trip blank, if analyzing for VOCs.

- C Record the information in the field logbook and complete all chain-of-custody records and field sheets (see Instruction F-1, "Documentation," in Appendix F).
- C Decontaminate the sampler.

C.3.4.7 Storm water runoff sampling techniques.

C.3.4.7.1 Applicability. Grab and flow-weighted composite samples are required to complete NPDES storm-permit requirements.

C.3.4.7.2 Method summary and equipment. Samples of storm water runoff are taken into the sample containers directly, or a bucket and transferred to the appropriate sample bottle containers.

C.3.4.7.3 Grab sampling procedure. The sampling procedure is as follows:

- C After rain begins to fall, record the date and time rain started to produce storm water runoff, facility number, outfall number, height of water in a measurement device (i.e., rain gauge), sample number, sample type, other items as directed on the NPDES storm water field sheet (see EPA/833/B-92/001).
- C Lower the sample container or stainless steel or PTFE sampling bucket into the center of the runoff flow where turbulence is at a maximum. Hold the sample container so the opening faces upstream. Avoid stirring up bottom sediments and keep sample free of uncharacteristic floating debris.
- C Allow the device to fill, using care not to overfill the bottle.
- C Preserve the sample as necessary and verify that the pH is sufficient for the criteria.
- C Verify that a PTFE liner is present in the cap. Secure the cap tightly.
- C Conduct visual observations as appropriate and record them in field log book.
- C Label the sample bottle with an appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Place filled sample containers on ice immediately along with the required trip blank, if analyzing for VOCs.
- C Record the information in the field logbook and complete the chain-of-custody form and field sheets (See Instruction F-1, "Documentation," in Appendix F).

C.3.4.7.4 Flow-weighted composite sampling procedure. Flow-weighted composite sampling techniques are appropriate for most chemical parameters, with the exception of those noted as requiring grab sampling techniques within C.3.2.2 and 40 CFR 136. The aliquots for flow-weighted composite samples must be collected within the first 3 hours (or during the entire event if the storm is less than 3 hours). Equal aliquots may be collected at the time of sampling and then flow-proportioned and composited in the laboratory, or the aliquots taken may be based on the flow rate at the time of sample collection and composited in the field. Regulations require that a minimum of 15 minutes must separate the collection of

each sample aliquot, and that a minimum frequency of three sample aliquots within each hour of discharge be maintained. To help meet regulatory requirements, suggest sample aliquots be collected at 20-minute intervals. Use the following procedure:

- C After rain begins to fall, record the date and time rain started to produce storm water runoff, facility number, outfall number, height of water in the measurement device (i.e., rain gauge), sample number, sample type, other items as directed on the NPDES storm water field sheet (see EPA/833/B-92/001).
- C Determine and record runoff flow at this time as noted within EPA/833/B-92/001. Determine appropriate volume for sample aliquot.
- C Lower the sample container (for lab compositing) or stainless steel or PTFE sample aliquot measuring device (for onsite compositing) into the center of the runoff flow where turbulence is at a maximum. Record the time and water depth. Hold the sample container so the opening faces upstream. Avoid stirring up bottom sediments and keep sample free of uncharacteristic floating debris.
- C Allow the device to fill with appropriate volumes based on flow observed, or suggest a minimum of 1000 mL be acquired for each aliquot (for lab compositing). NOTE: The laboratory should also be consulted to determine the overall sample volumes necessary for the required analyses to ensure that sufficient volumes of individual sample aliquots are collected to support the composite sample.
- C Repeat the steps for bullets 2-4 for each aliquot of the composite sample, retaining each storm water sample aliquot in separate, labeled sample containers. As stated in Section C.3.4.7.4, regulations dictate a minimum frequency of three sample aliquots within each hour of the storm event for the first 3 hours or duration of the storm event, if less than 3 hours.
- C If field compositing is performed and after the sample aliquots have been collected, combine appropriate volumes of sample aliquots into stainless steel or PTFE bucket to create the flow-weighted composite sample. Fill appropriate sample bottles with the composite sample mixture, using care not to overfill the bottle.
- C Preserve the sample if necessary and verify that the pH is sufficient for the criteria.
- C Verify that a PTFE liner is present in the cap. Secure the cap tightly.
- C Conduct visual observations as appropriate and record them in field logbook.
- C Label the sample bottle with an appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Place filled sample containers on ice immediately.
- C Record the information in the field logbook and complete the chain-of-custody form and field sheets (see Instruction F-1, "Documentation," in Appendix F).

C.3.4.8 Emerging and innovative sampling procedures.

C.3.4.8.1 Disadvantages of standard samplers. All of the standard samplers presented previously for the sampling of surface water disrupt equilibrium during the sampling event. This may lead to obtaining a sample that is not representative of the actual environmental conditions or contaminant concentrations. These routine sampling techniques also acquire a one-time sample, which reflects only environmental conditions at the time of sampling, and they are unable to assess episodic contamination. Additionally, there is little understanding of the correlation between routine surface water sample results and the concentrations of truly dissolved or bioavailable contaminants. Many of the Applicable, Relevant, and Appropriate Requirements (ARARs) for surface water, which are aquatic toxicity data or water quality criteria, are based on dissolved contamination concentrations. Therefore, the use of standard sampling techniques to generate data for comparison with these criteria may not be appropriate.

C.3.4.8.2 New sampling devices and procedures. New sampling devices and sampling procedures have been designed to minimize the disturbance to the medium during sampling to minimize any bias in the results. Recent studies have shown the application of semipermeable membrane devices (SPMDs) to the sampling of surface water bodies (Petty et al. 1995; Ellis et al. 1995). This type of sampler is designed to mimic the bioconcentration process by capturing only the dissolved/bioavailable contaminant concentrations and is an alternative to performing tissue analyses of various species or aquatic organisms. It is also unique in that it assesses episodic contamination, due to the residence time within the medium under investigation. Although the use of this technique may not be fully accepted by a data user or regulating authority without some initial redundancy to routine procedures, the advantages it offers are compelling. SPMDs are commercially available; easy to deploy, retrieve, and sample; and very low maintenance. They are also able to detect contaminants at lower concentrations than routine surface water samples due to their ability to concentrate the contaminants within the lipid phase, as well as extending residence times, which may further enhance contaminant detection at low levels.

C.3.4.8.3 SPMDs. SPMDs (Figures C-8 and C-9) are constructed of thin-walled nonporous polymer lay-flat tubes (of low-density polyethylene, polypropylene, PVC, or silicone) containing a large molecular weight (\$600 daltons) nonpolar liquid (of neutral lipids - such as triolein, or silicone fluids) as a sequestered medium. The SPMD is housed within a protective shroud to avoid damage to the SPMD during sampling events. The semipermeable membrane (i.e., high-density polyethylene) film has pore sizes of approximately 10 D, which effectively control the rate of dissolved contaminants uptake into the device. The SPMD capacity to sequester organic contaminants is dependent on the lipid/water partition coefficient K_{LW} for that organic target analyte. This K_{LW} value can be approximated from the value for the octanol/water partition coefficient K_{ow} for the target analyte. SPMDs may be suspended to a specified depth (e.g., 0.5 or 1 m) of the surface water body, secured by floats and anchors for a period of several days to weeks. In general, the rate of contaminant uptake increases as water temperature increases and decreases as the device is biofouled by aquatic organisms. If water is clear and photosensitive compounds are being evaluated, the SPMD should be shaded to reduce contaminant loss through degradation. Heterotrophic growth may be minimized by periodic treatment (dipping) of the SPMD into a biocide, and/or the protective shroud may be manufactured of materials (i.e., copper screen) that inhibit biofouling. Post sampling, the SPMDs are collected and placed in clean jars or cans on ice for cooling. Ship SPMD samples to the laboratory within 24 hours. Holding time studies for SPMDs have been sporadic and have not assessed all potential contaminants. However, one study determined that freezing of SPMDs caused no loss of herbicide concentrations during 6 months.

C.3.4.8.4 SPMD uses. SPMDs may be used to screen for polynuclear aromatic hydrocarbons (PAHs), organochlorine pesticides, polychlorinated biphenyls (PCBs), herbicides, methyl mercury complexes, alkylated selenides, etc. Unfortunately, the analytical chemistry and data reduction procedures used for SPMDs are more labor intensive than routine environmental samples. Generally, the analytical procedures involve the following: initial cleaning and integrity inspection of the membrane; spiking SPMD media with

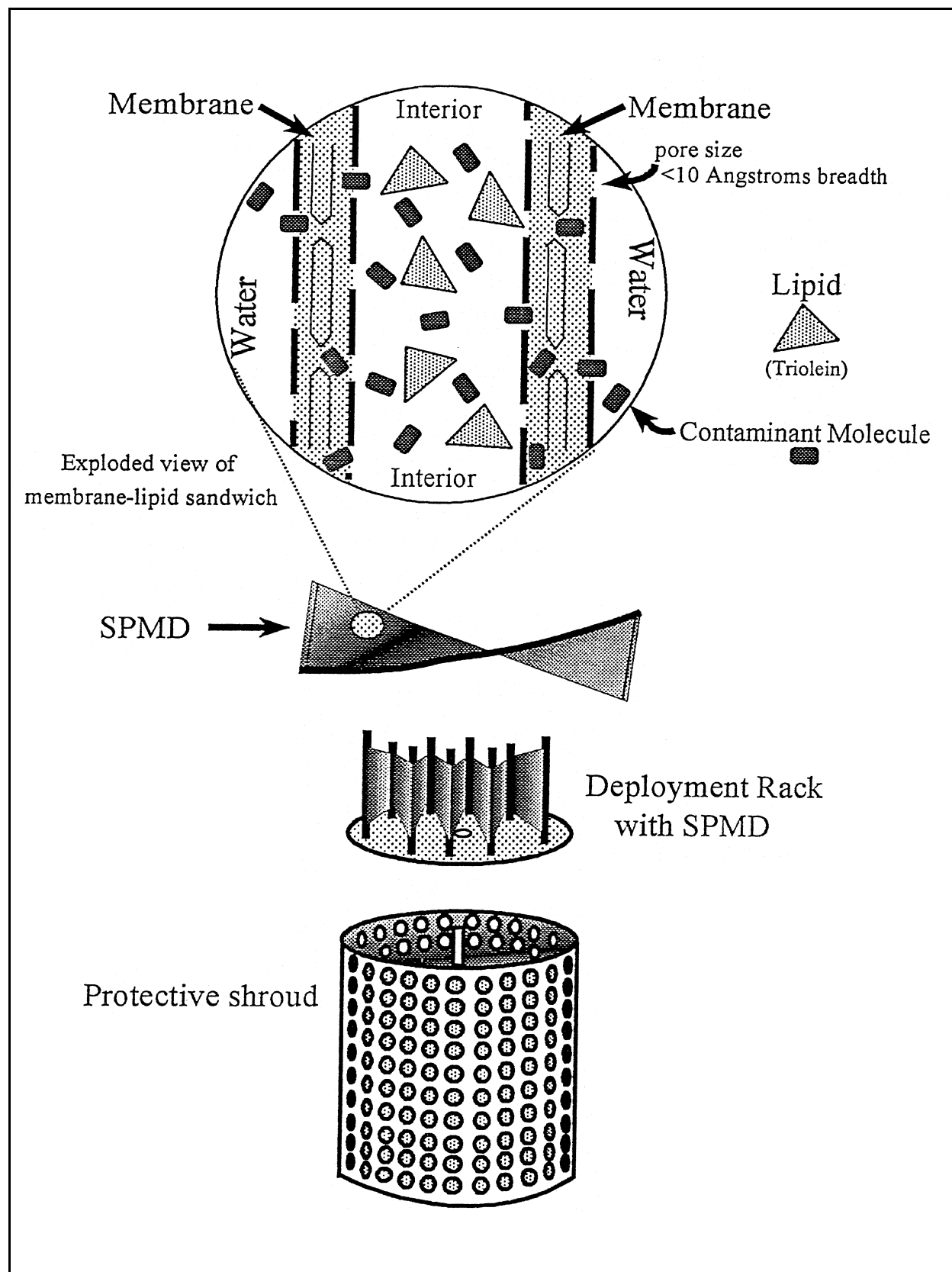


Figure C-8. Schematic of a semipermeable membrane device (SPMD)

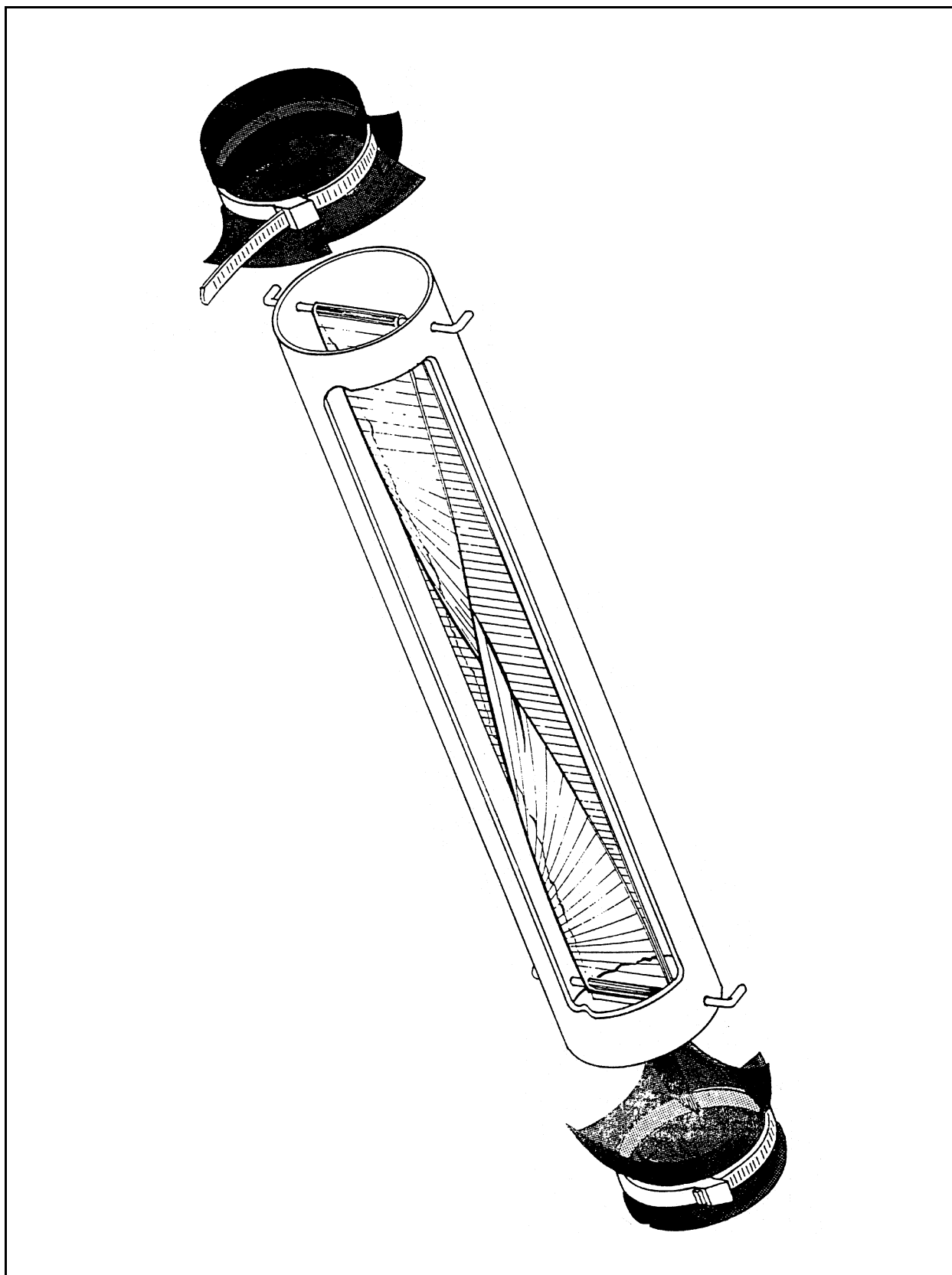


Figure C-9. Cutaway representation of an SPMD and protective shroud

surrogates or internal standards; placing SPMD in an appropriate solvent (i.e., hexane) to perform dialysis; undergoing sulfur cleanup of dialysates (if applicable); performing size exclusion chromatography (i.e., gel permeation column); performing additional chromatographic cleanups (florisil, silica gel); and performing final solvent exchange (if applicable) and solvent reduction procedures. Finally the extract undergoes analysis by gas chromatograph or high-performance liquid chromatograph configured with appropriate detectors. Currently, a major disadvantage of SPMDs is that few environmental laboratories have any experience with dialysis procedures. Concentrations of contaminants from SPMD data are calculated with information from these partitioning coefficients, the uptake rate constant, and exposure times. Refer to Petty et al. (1995) and Ellis et al. (1995) for details on the mathematical model used for this calculation.

C.3.5 Decontamination procedures. All equipment that will enter the water must be decontaminated prior to its entry. The inside surface of pumps and tubing apparatus must be decontaminated by drawing the decontamination solution through the equipment. Sampling equipment should be decontaminated, as described in Instruction E-6 (Appendix E). The sampling equipment should be placed in plastic bags until immediately prior to use. Additional sampling devices may be needed onsite to ensure an adequate drying time. During transport and storage, sampling equipment and sample bottles must be physically separated from engines/ generators that are used to power some sampling equipment.

C.3.6 Field control samples requirements. Field control samples are collected by the sampling team to determine whether the data are of suitable quality. They include blanks, replicates, and/or background (upgradient) samples. QA samples are replicates sent to a referee (QA) laboratory and analyzed to evaluate the contractor's laboratory performance. QC samples are blind replicates collected by the sampling team for analysis by the primary laboratory. A detailed discussion of field control samples is presented in Instruction G-2 (Appendix G).

C.3.7 Documentation requirements. Bound field logbooks should be used for the maintenance of field records. Record all aspects of the site setup, sample collection, and handling as outlined above and in Instruction F-1 of Appendix F.

C.4 Potable Water Sampling

C.4.1 Scope and application. This instruction presents guidelines for collecting representative potable water (tap water) samples. Discussions are based on the assumption that a supply tap is available for sampling the selected location, for example, a residence. Under this assumption the only applicable sampling method would be the hand-held bottle. The sampling methods discussed in Instruction C-2, “Ground Water Sampling,” or C-3, “Surface Water Sampling,” should be reviewed if other sampling methods are required for collecting a sample. Discussions presented in this section are a review of the protocols and procedures that should be used when collecting water samples from a tap.

C.4.2 Sampling strategies. Sampling strategies are developed by the project team to satisfy project-specific data needs that are identified in the HTRW technical planning process. The sampling strategy developed at a particular site will influence several project decisions, including, but not limited to, sampling locations, type of samples, sampling frequency, and sampling and analytical protocols. Sampling strategies may be significantly influenced by such factors as physical site constraints, safety, and cost, to name a few. The technical planning process that results in the development of the sampling strategy is critical because of the difficulty in acquiring representative samples, the reduction of contaminant action levels, and the problems associated with trace level cross-contamination. Successful investigations of hazardous waste sites are highly dependent on an effective sampling scheme. Development of a sampling scheme for purposes of characterizing a hazardous waste site should follow the fundamentals of the scientific approach. A successful sampling scheme requires a logical design to allow an evaluation of potential contaminants in relation to background conditions and contaminant degradation in various media.

C.4.2.1 Sampling locations. Potable water is usually sampled in an attempt to discover contamination and to define its variability. With such an objective, it is most logical to choose sample locations that will yield the most information about the water supply system. When a site is evaluated, sampling can be conducted by random, systematic, or biased sampling. Biased samples are those collected at locations that were chosen based on historical information, knowledge about the behavior of the contaminant(s), and/or knowledge about the effects of the physical system on the fate of the contaminant. Random sampling depends on the theory of random chance probabilities to choose the most representative sample. Potable water samples may also be collected for evaluating contamination in a particular well, assessing contamination due to a water piping system, or identifying the need for alternate water supply systems. When residential wells are sampled, the sample tap should not be located after a household purification system (i.e., water softening or filtration). In these cases an outdoor tap may have to be sampled. During assessment of water piping systems, contamination of both the hot and cold water sources should be considered. Depending upon the project data quality objectives (DQOs) and/or tap configuration, this may entail the acquisition of individual hot and cold water source samples, or opening both taps simultaneously during the sampling activity. Often biased sampling techniques are used to identify potentially contaminated or impacted areas. Water taps are stationary and are typically sampled for purposes of evaluating drinking water regulations or contaminant impact on local drinking water supplies. Selection of a sampling location is an investigation objective.

C.4.2.2 Type of sample. The type of sample should be designated when selecting a sampling method. Potable water samples are typically discrete samples. A discrete (grab) sample is defined as a discrete aliquot representative of a specific location at a given point in time. The sample is collected at once and at one particular point in the sample matrix. The representativeness of such samples is defined by the nature of the materials being sampled. In general, as sources vary over time and distance, the representativeness of grab samples will decrease.

C.4.2.3 Suggested samplers. The sample container is normally used to collect a potable water sample. Use of additional sampling equipment is not recommended. Sample disturbance, sample volume, and chemical/physical reactivity between potential contaminants and the sampling container should be considered when collecting the potable water sample.

C.4.2.4 Sample frequency. Determination of the number of samples needed to characterize a site is also dependent upon the objectives and site-specific conditions. For example, if the objective of the event is to determine whether the site is contaminated, a limited number of samples from properly chosen locations will yield useful information. If, however, additional factors influencing contamination are the objectives, a greater number of samples may be needed. Timing for collecting samples may also be crucial. In many cases statistical considerations can be helpful in determining sampling strategy.

C.4.3 Sample preservation and handling. Because many of the chemical constituents and physicochemical parameters that are to be measured or evaluated in potable water monitoring programs are not chemically stable, sample preservation is required. Appropriate preservation techniques for various parameters and sample containers that the sampler should use for each constituent or common set of parameters are specified in Appendix B. These preservation methods and sample containers are based on EPA/SW-846. Procedures and techniques for transporting the samples to the offsite laboratory are discussed in Instruction F-2, "Packaging and Shipping Procedures," in Appendix F. Improper sample handling may alter the analytical results of the sample, causing the results to be invalid. Samples should be collected in the container that is required for that analysis or set of compatible parameters and be in sufficient volumes to allow the appropriate analyses. The sample should then be preserved in the field as specified in Appendix B. Because of the low analytical detection limits that are required for assessment of drinking water standards and risk assessment data uses, care must be taken when collecting the sample to avoid the loss of any contaminants. Samples for volatile analysis should be taken in a manner that minimizes contaminant loss through agitation/volatilization. Samples should be collected in the order of the parameters listed in Section C.4.3.1. When more than one container is required per parameter, the sample should be equally split among all containers until they are filled. Containers used to collect samples for organic analyses should not be prerinsed with water because of the possibility of preservation loss or the loss/gain of contaminants that could taint the analytical results.

C.4.3.1 Sample containers. When metals are the analytes of interest, high-density polyethylene containers with PTFE-lined polypropylene caps should be used. When organics are the analytes of interest, glass bottles with PTFE-lined caps should be used. Refer to Appendix B or the specific analytical method to designate an acceptable container. Containers should be cleaned based on the analyte of interest. Instruction E-6, "Decontamination Procedures," Appendix E, contains additional information on appropriate glassware cleaning protocols. If precleaned bottles are used, the cleanliness of each lot of precleaned bottles should be verified by the container supplier or in the laboratory and appropriate paperwork (i.e., certificates) retained with other field documentation. Refer to Appendix B for information on the required size, number, and type of sample containers. Samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. A preferred collection order for some common parameters follows:

- VOA
- POC
- POX
- TOX

- TOC
- Extractable organics
- Total metals
- Dissolved metals
- Phenols
- Cyanide
- Sulfate and chloride
- Turbidity
- Nitrate and ammonia
- Radionuclides

C.4.3.2 Sample preservation. Methods of sample preservation are relatively limited and are generally intended to retard biological action and hydrolysis and reduce sorption effects. Preservation methods are generally limited to pH control, chemical addition, refrigeration, and protection from light. Prepreserved sample containers are not recommended. Because of the potential for preservative loss if field errors occur, or if different amounts of preservative may be necessary to bring the sample to the required pH, it is recommended to add the preservative to the container in the field and verify that the pH of the sample has been achieved. This information should be documented within field logbooks. The sampler should refer to Appendix B or the specific preservation method in EPA/SW-846 for the appropriate preservation technique.

C.4.3.3 Special handling for VOA samples. Water samples to be analyzed for purgeable organic compounds should be stored in 40-mL septum vials with screw caps. Septa should be placed on the sample bottle so that the PTFE side is in contact with the sample. The 40-mL vials should be completely filled to prevent volatilization, and extreme caution should be exercised when filling a vial to avoid any turbulence that could also produce volatilization. The sample should be carefully poured down the side of the vial to minimize turbulence. As a rule, it is best to gently pour the last few drops into the vial so that surface tension holds the water in a convex meniscus. The septum is then applied and some overflow is lost, but air space in the bottle is eliminated. The bottle is then capped and should be turned over and tapped to check for bubbles. If any bubbles are present, the procedure must be repeated. Care should be taken to ensure that no loss of preservative occurs, if applicable.

C.4.3.4 Special precautions for trace contaminant sampling. Contaminants can be detected in the parts per billion and/or parts per trillion ranges. Therefore, extreme care must be taken to prevent cross-contamination of these samples. The following general precautions should be taken when sampling:

- A clean pair of new, disposable gloves should be worn each time a different location is sampled and gloves should be donned immediately prior to sampling.

- Sample containers for source samples or samples suspected of containing high concentrations of contaminants should be placed in separate plastic bags immediately after collecting, preserving, tagging, etc.
- If possible, background samples and source samples should be collected by different field teams. If different field teams cannot be used, all background samples shall be collected first and placed in separate ice chests or shipping containers. Samples of waste or highly contaminated samples should never be placed in the same ice chest as environmental samples. It is good practice to enclose waste or highly contaminated samples in a plastic bag with activated carbon to minimize cross-contamination potential.
- If possible, one member of the field team should take all the notes, fill out sample tags, field sheets, etc., while the other members collect all of the samples.
- Sample collection activities should proceed progressively from the suspected least contaminated area to the suspected most contaminated area.
- Field personnel should use equipment constructed of PTFE, stainless steel, or glass that has been properly precleaned. PTFE or glass is preferred for collecting samples where trace metals are of concern.
- Adequate field control samples should be collected.

C.4.4 Sampling methods. When potable water is being sampled, utmost care must be taken to ensure that samples are representative of the water being sampled. This is important not only from a technical and public health perspective, but also from a public relations standpoint. Poor sampling techniques may result in incorrect results (either by not detecting a compound that is present or by contaminating the sample and falsely indicating a compound that is not present). If incorrect results are disclosed to the public, it may be impossible to change public opinion when correct results are reported. As discussed in Appendix C-2, "Ground Water Sampling," potable water wells must be purged before the sample is collected. This procedure ensures that water representative of the formation or source is sampled. The tap should be opened and allowed to flow to purge the system. Sampling should be performed after the DO, pH, conductivity, temperature, turbidity, and redox potential (if necessary) have reached equilibrium. The initial purging procedure ensures that any contaminants that might have entered the area of the tap from external sources have been avoided. Potable water samples should be representative of the water quality within the household or office under investigation. The sampling tap must be protected from exterior contamination associated with being too close to the sink bottom or to the ground. Contaminated water or soil from the faucet exterior may enter the bottle during the collecting procedure since it is difficult to place a bottle under a low tap without grazing the neck interior against the outside faucet surface. Leaking taps that allow water to flow from around the stem of the valve handle and down the outside of the faucet or taps in which water tends to run up on the outside of the lip are to be avoided as sampling locations. Aerator, strainer, and hose attachments on the tap must be removed before sampling. These devices can harbor a bacterial population if they are not cleaned routinely or replaced when worn or cracked. Whenever a steady stream of water cannot be obtained from taps, after such devices are removed, a more suitable tap should be sought. Taps where the water flow is not steady should be avoided because temporary fluctuation in line pressure may cause sheets of microbial growth or scale that are lodged in some pipe section or faucet connection to break loose. A smooth-flowing water stream at moderate pressure without splashing should be obtained. Then, without changing the water flow, which could dislodge some particles in the faucet, the samples can be collected. Occasionally, samples are collected to determine the contribution of transmission pipes, water

coolers, water heaters, etc., to the quality of water in private residences, offices, etc. The purpose of these investigations may be to determine if metals, e.g., lead, are being dissolved into the water supply. In these cases, it may be necessary to ensure that the water source has not been used for a specific time interval, e.g., over a weekend or a 3- or 4-day holiday period. Samples collected may consist of one sample of the initial flush and another sample after the indicator parameters have reached equilibrium. Regardless of the type of sample bottle being used, the bottle septum and/or cap should not be placed on the ground or in a pocket. Instead, the bottle should be held in one hand and the septum and/or cap in the other, using care not to touch the PTFE side of the septa or inside of the cap. Exercise care not to lose the PTFE liner in certain bottle caps. Contaminating the sample bottle with fingers or permitting the faucet to touch the inside of the bottle should be avoided. Sample bottles should not be rinsed before use. When filling any container, care should be taken not to splash drops of water from the ground or sink into either the bottle or cap. To avoid dislodging particles in the pipe or valve, the stream flow should not be adjusted while sampling. Name(s) of the resident or water supply owner/operator and the resident's exact mailing address, as well as his or her home and work telephone numbers, should always be obtained. This information is required to inform the residents or water supply owner/operators of the results of the sampling program.

C.4.4.1 Hand-held Bottle.

C.4.4.1.1 Applicability. Filling the sample containers directly is advantageous when the sample might be significantly altered during transfer from a collection vessel into another container. This would affect samples collected for VOC analysis.

C.4.4.1.2 Method summary and equipment. Samples can be readily collected by directly filling the sample containers.

C.4.4.1.3 Sampling procedure. The sampling procedures previously discussed in this section should be addressed, if appropriate. The following are additional sampling procedures:

- C If applicable, place plastic sheeting on the ground surface to prevent cross- contamination of samples.
- C If applicable, remove aerator, strainer, and hose attachments on the tap before sampling.
- C Purge well or source and tap lines initially at a high flow rate for a minimum of 5 to 10 minutes. Then adjust the flow to low to moderate and verify that the DO, pH, specific conductance, temperature, and turbidity are each at equilibrium. Equilibrium is established as follows: ± 10 percent for DO, ± 0.2 pH units, ± 3 percent for specific conductance, ± 1 degree Celsius for temperature, and ± 10 percent for turbidity. (If redox potential is used as an indicator, ± 10 mV should be used as the stabilization criterion.)
- C Begin sampling by filling the sample containers slowly and continuously following the parameter order and guidance outlined in this instruction.
- C Preserve the sample if necessary and verify that the pH is sufficient for the criteria.
- C Check that a PTFE liner is present in the cap. Secure the cap tightly. Refer to C.4.3.3 for instructions on capping of VOA samples.

- C Label the sample bottle with an appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Place filled sample containers on ice immediately, along with the required trip blanks if analyzing for VOCs.
- C Record the information in the field logbook and complete the chain-of-custody form and field sheets (see Instruction F-1, "Documentation," in Appendix F).

C.4.5 Field control samples requirements. Field control samples are collected by the sampling team to determine whether the data are of suitable quality. They include blanks, replicates, and/or background or upgradient samples. QA samples are replicates sent to a referee (QA) laboratory and analyzed to evaluate the contractor's laboratory performance. QC samples are blind replicates collected by the sampling team for analysis by the primary laboratory. A detailed discussion of field control samples is contained in Instruction G-2, Appendix G.

C.4.6 Documentation requirements. Bound field logbooks should be used for the maintenance of field records. Record all aspects of the sample collection and handling as outlined previously and in Instruction F-1, Appendix F.

C.5 Sediment Sampling

C.5.1 Scope and application. This section presents guidelines for collecting representative sediment and sludge samples from surface water bodies. Sediment can be considered as any material that is submerged/saturated (at least temporarily) or suspended in any surface water body. This includes sludges, lake bottom sediments, perennial and intermittent stream sediments, and marine sediments. For discussion purposes, sampling devices are classified into the following categories according to applicability: surface sediments/shallow water (scoop and tube samplers), subsurface sediments/shallow water (hand auger/tube sampler, and hand-driven split-spoon sampler), surface sediments/deep water (Ponar, Ekman, and Smith-McIntyre samplers), and subsurface sediments/deep water (gravity and piston corer, vibratory coring device, and box core sampler).

C.5.2 Sampling strategies. Sampling strategies are developed by the project team to satisfy project-specific data needs that are identified in the HTRW technical planning process. The sampling strategy developed for a particular site will influence several project decisions, including, but not limited to, sampling locations, types of samples, sampling frequency, and sampling and analytical protocols. For instance, generation of an ecological risk assessment may require the need for colocated surface water and sediment samples. Sediment sampling must also determine whether the biota and/or underlying sediments are to be evaluated. Sampling strategies may be significantly influenced by such factors as physical site constraints, safety, and cost, to name a few. Additionally, the complexity, dynamic nature, and thin stratification of sediments may pose special challenges when determining appropriate sampling protocols. The technical planning process that results in the development of the sampling strategy is critical because of the difficulty in acquiring representative samples, the typically low-level contaminant action levels associated with sediments, and the problems associated with trace level cross-contamination. Successful investigations of hazardous waste sites are highly dependent on an effective sampling scheme. Development of a sampling scheme for purposes of characterizing a hazardous waste site should follow the fundamentals of the scientific approach. A successful sampling scheme requires a logical design to allow an evaluation of potential contaminants in relation to background conditions, vertical extent, horizontal extent, and mobility in various media. The USEPA is also an important source for guidance on sediment sampling. QA/QC guidance for sampling and analysis of sediments may be found in EPA/823/B-95/001.

C.5.2.1 Sampling locations. Sampling at hazardous waste sites is usually conducted in an attempt to discover contamination and to define its extent and variability. With such an objective, it is most logical to choose sample locations that will yield the most information about site conditions. During evaluation of a site, sampling can be conducted by random, systematic, or biased sampling. Biased samples are those collected at locations that were chosen based on historical information, knowledge about the behavior of the contaminant(s), and/or knowledge about the effects of the physical system on the fate of the contaminants. Random sampling depends on the theory of random chance probabilities to choose the most representative sample. Often biased and random sampling techniques can be used together to address an entire site thoroughly. Some samples may be biased to potentially contaminated areas (e.g., lagoons, former process or disposal areas) or potentially impacted areas (e.g., sediment downstream from a discharge pipe, or exposure area of a susceptible population). In areas less likely to be contaminated or areas with little available background information, random samples may be used to allow adequate assessment of the entire site. Due to the nature of the media, locations for collecting sediment samples are restricted to those within the water body under evaluation. Variations of locations for collecting sediment samples include sample location and depth. Sediment depositional patterns should be considered against the sample objectives when deciding the sediment sample locations. These patterns differ between standing and flowing bodies of water. Generally, for flowing water (e.g., streambeds or riverbeds), the depositional areas are normally found inside bends and downstream of islands or obstructions. Areas directly downstream of the joining of two streams should be avoided because the flows and sediments may not immediately mix. For standing water bodies,

the center of the mass or a discharge point should be sampled for sediments. As discussed in Section C.5.2, selection of sample locations should satisfy investigation objectives.

C.5.2.2 Types of samples. The type of sample should be designated when selecting a sampling method. Sediment samples can be discrete (grab) or composite. A discrete (grab) sample is defined as a discrete aliquot representative of a specific location at a given point in time. The sample is collected at once and at one particular point in the sample matrix. The representativeness of such samples is defined by the nature of the materials being sampled. In general, as sources vary over time and distance, the representativeness of grab samples will decrease. Composites are samples composed of more than one specific aliquot (discrete samples) collected at various sampling locations or depths. Analysis of this type of sample produces an average value and can in certain instances be used as an alternative to analyzing a number of individual grab samples and calculating an average value. It should be noted, however, that compositing can mask the presence of contaminants by diluting isolated concentrations of analytes that may be present in the environmental matrix. When surficial sediments are sampled, the objectives of a project should determine whether any organic matter or strictly sediments should be sampled. The organic matter present may represent the primary contaminant source that aquatic species uptake.

C.5.2.3 Suggested samplers. Samplers for this medium are dictated significantly by project objectives of surficial versus subsurface samples and site constraints of the water depth. Each sampling technique presents various disadvantages and advantages for its application. For example, sample disturbance, sample volume, chemical/physical reactivity between potential contaminants and sampling tool materials, and ease of decontamination vary from technique to technique. The advantages and disadvantages of each sampling technique are discussed in the following sections.

C.5.2.4 Sample frequency. Determination of the number of samples needed to characterize a site is also dependent upon sampling objectives and site-specific conditions. For example, if the objective of the event is to determine whether the site is contaminated, a limited number of samples from properly chosen locations will yield useful information. If, however, the site is known to be contaminated and delineation of the contamination is the objective, a greater number of samples may be needed. In many cases, statistical considerations can be helpful in determining sampling strategy.

C.5.3 Sample preservation and handling. Many of the chemical constituents and physicochemical parameters that are to be measured or evaluated in investigation programs are not chemically stable; therefore, sample preservation is required. Appropriate preservation techniques for various parameters are specified in Appendix B. In addition, sample containers that should be used for each constituent or common set of parameters are specified in Appendix B. These preservation methods and sample containers are based on EPA/SW-846. Procedures and techniques for transporting the samples to the offsite laboratory are discussed in Instruction F-2, "Packaging and Shipping Procedures," in Appendix F. Improper sample handling may alter the analytical results of the sample, causing the results to be invalid. When subsequent analysis allows, sediment samples should be collected using a clean stainless steel scoop, spoon, or trowel and placed into a clean stainless steel or other appropriate homogenization container. The sample should be mixed thoroughly to obtain a homogeneous, representative sample prior to placement into the sample container. Refer to Instruction E-2 of Appendix E for a discussion of homogenization procedures. When compositing of samples collected from different locations or depths is desired, all components of the composite sample are mixed in the homogenization container before the composite sample is placed in the sample container. Refer to Instruction E-3 of Appendix E for a discussion of compositing procedures. The sample should then be preserved in the field as specified in Appendix B. Because of the low analytical detection limits that are required for certain data uses, care must be taken when collecting the sample to avoid the loss or gain of any contaminants. For example, the samples packaged for volatile analysis should not be

homogenized or composited. They should be taken as described in Instruction E-4, "Collection, Handling, and Storage of Solid Samples for VOC Analysis" (Appendix E).

C.5.3.1 Sample containers. When metals are the analytes of interest, wide-mouth glass containers with PTFE-lined polypropylene caps should be used. When organics are the analytes of interest, glass bottles with PTFE-lined caps should be used. Refer to Appendix B or the specific analytical method to designate an acceptable container. Containers should be cleaned based on the analyte of interest. Instruction E-6, "Decontamination Procedures," Appendix E, contains additional information on appropriate glassware cleaning protocols. If precleaned bottles are used, the cleanliness of each lot of precleaned bottles should be verified by the container supplier or in the laboratory and appropriate paperwork (i.e., certificates) retained with other field documentation. Refer to Appendix B for information on the required size and type of sample containers. Samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. A preferred collection order for some common parameters follows:

- VOA
- POC
- POX
- TOX
- TOC
- Extractable organics
- Total metals
- Phenols
- Cyanide
- Sulfate and chloride
- Turbidity
- Nitrate and ammonia
- Radionuclides

C.5.3.2 Sample preservation. Methods of sample preservation are relatively limited and are generally intended to retard biological action and hydrolysis and to reduce sorption effects. Preservation methods for sediment samples are dependent on the type of analyses. For nonvolatile analyses, sample preservation is generally limited to refrigeration and/or protection from light. Volatile sediment sample preservation is based on whether the analysis is to be low-level or medium-level analysis. Refer to Instruction E-4 of Appendix E for details. The sampler should refer to Appendix B or the specific preservation method in EPA/SW-846 for the appropriate preservation technique.

C.5.3.3 Special handling for VOA samples. Samples to be analyzed for purgeable organic compounds should be acquired as described in Instruction E-4 of Appendix E, "Collection, Handling, and Storage of Solid Samples for VOC Analysis."

C.5.3.4 Special precautions for trace contaminant sampling. Contaminants can be detected in the parts per billion and/or parts per trillion ranges. Therefore, extreme care must be taken to prevent cross-contamination of these samples. The following general precautions should be taken when sampling:

C.5.3.4.1 A clean pair of new, disposable gloves should be worn each time a different location is sampled and gloves should be donned immediately prior to sampling.

C.5.3.4.2 To prevent cross-contamination between samples, it is suggested that the multiple VOA vials from each sampling location be sealed in separate smaller plastic bags when the sampled medium is suspected of containing high concentrations of volatile organics.

C.5.3.4.3 Sample containers filled with source or waste samples or samples suspected of containing high concentrations of contaminants should be placed in separate plastic bags immediately after collecting and preserving, and activated carbon should be included in the bags to prevent cross-contamination.

C.5.3.4.4 If possible, background samples and source samples should be collected by different field teams. If different field teams cannot be used, all background samples should be collected first and placed in separate ice chests or shipping containers. Samples of waste or highly contaminated samples should never be placed in the same ice chest as environmental samples. It is good practice to enclose waste or highly contaminated samples in a plastic bag before placing them in ice chests. Ice chests or shipping containers for source samples or samples suspected to contain high concentrations of contaminants should be lined with new, clean, plastic bags.

C.5.3.4.5 If possible, one member of the field team should take all the notes, fill out sample tags, field sheets, etc., while the other members collect all of the samples.

C.5.3.4.6 Sample collection activities should proceed progressively from the suspected least contaminated area to the suspected most contaminated area.

C.5.3.4.7 Field personnel should take precautions to prevent contamination from sampling equipment. Some sediment samplers, particularly grab samplers, are constructed of metal and some may be electroplated or painted to prevent corrosion. PTFE-coated or stainless steel samplers are preferable. All samplers should be properly decontaminated before each use. When grab samplers are used, samples should be taken from the center of the mass of sediment retrieved by the sampler, avoiding material that has come in contact with the walls of the sampler. Liner materials or tubes for tube samplers should be selected to avoid sample contamination. For example, plastic liners or tape used to seal containers may be a source of contamination for organic compounds.

C.5.3.4.8 Adequate field control samples should be collected.

C.5.4 Sampling methods. Prior to sample collection, water body characteristics (size, depth, flow) should be recorded in the field logbook. Sampling should proceed from downstream locations to upstream locations so that disturbance from sampling does not affect sampling quality. Additionally, if surface water samples will be collected at the same locations as sediment samples, the water samples must be collected first. Factors that contribute to selection of a sampler include the width, depth, flow, and bed characteristics of the surface water body to be sampled, the volume of sample required, and whether the sample will be collected from the shore or a vessel. In collecting sediment samples from any source, care must be taken to

use appropriate sampling devices that minimize disturbance and sample washing as the sample is retrieved through the liquid column. Sediment fines may be carried out of the sample during collection and retrieval if the liquid above is flowing or deep. This may result in collection of a nonrepresentative sample due to the loss of contaminants associated with these fines. While a sediment sample is usually expected to be a solid matrix, the sampler should not place the sample in the sample bottle and then decant the excess liquid. If the sample is collected properly, any liquid in the bottle is representative of sediment conditions. As with surface water sampling, tidal influence on the water body should be determined, and the effect of the tide on the sediment sample collection should be detailed in the sampling plan. Consideration should be given to sampling at varied tidal stages. In addition, the stage of the tide at the time of sample collection should be recorded. In some instances, the dimensions of the water body dictate that a barge or boat must be used. The barge or boat should be positioned upstream (if there is flowing water) of the desired sample location. As the sampler is lowered it may be carried slightly downstream, depending upon the device used and the force of the flow. The device chosen for sample collection in this case will, again, depend upon the depth and flow of the liquid above the sample location and the bed characteristics of the surface water. The following are sampling instructions for the most common techniques for collecting sediment and sludge samples. For additional information see EM 1110-1-1906, EM 1110-2-5027, Plumb (1981), Mudrock and MacKnight (1991), and Spigolon (1993a, b). In addition, a comparison of the general characteristics of various sediment-sampling devices for chemical, physical, and biological studies can be found in ASTM D 4387, D 4823 and E 1391. The most appropriate device for a specific study depends on the study objectives, sampling conditions, parameters to be analyzed, and cost-effectiveness of the sampler. There are basically three types of devices used to collect sediment samples: dredges, grab samplers, and corers.

- A **dredge** is a vessel that is dragged across the bottom of the surface being sampled, collecting a composite of surface sediments and associated benthic fauna. This type of sampler is used primarily for collecting indigenous benthic fauna rather than samples for chemical analyses. Because the sample is mixed with the overlying water, no pore-water studies can be made of dredged samples. Additionally, because the walls of the dredge are typically nets, they act as a sieve and only the coarser material is trapped, resulting in the loss of fine sediments and water-soluble compounds. As noted earlier, this sample washing may potentially bias results to the low side. At best, results of dredge sampling are considered qualitative since it is difficult to determine the actual surface sampled by the dredge. For these reasons, dredge samplers are not addressed within this instruction.
- **Grab** samplers have jaws that close by a trigger mechanism upon impact with the bottom surface. Grab samplers offer the advantage of being able to collect a large amount of material in one sample, but they have the disadvantage of giving an unpredictable depth of penetration. Substantial contaminant variation with depth is unlikely in shallow channel areas without direct contamination inputs, in areas that have frequent ship traffic, or from sediments that are dredged at short intervals. In these situations, bottom sediments are frequently resuspended and mixed by ship scour and turbulence, effectively preventing stratification. In such cases, surface grab samples represent the mixed sediment column. Grab samplers are also appropriate for collecting surficial samples of reference or control sediments.
- **Core** samplers are basically tubes that are inserted into the sediment by various means to obtain a cylinder or box sample of material at known depths. Corers can be simple, hand-operated devices used by scuba divers, or they can be large, costly, motor-driven mechanisms that can collect samples from great depths. Corers are recommended whenever sampling to depth is required, or when the variation in contamination with depth is of concern. However, this type of data is necessary only if excavation of infrequently disturbed sediments below the mixed layer is planned. A few types of corers are a gravity corer, a piston corer, a vibra-corer, a split-spoon

core sampler, and a box core sampler. The choice of corer design depends on factors such as the objectives of the sampling program, sediment volumes required for testing, sediment characteristics, water depth, sediment depth, and currents or tides.

C.5.4.1 Surface sediments/shallow water: Scoop or trowel. Method Reference: ASTM D 5633.

C.5.4.1.1 Applicability. The scoop or trowel method is a very accurate procedure for collecting representative samples. This method can be used in many sampling situations but is limited to sampling exposed sediments or sediments in surface waters less than 150 mm (6 in.) deep, with nominal flow. The scoop or trowel sampler is not effective for sampling in waters more than 150 mm (6 in.) deep, or when flow causes a loss of fines from sample washing.

C.5.4.1.2 Method summary and equipment. The simplest, most direct method of collecting sediment samples is with the use of a stainless steel scoop or trowel (Figure C-10). A stainless steel scoop or trowel can be used to collect the sample, and a stainless steel bowl can be used to homogenize the sample when applicable to the subsequent analysis. The scoop or trowel should not be chrome-plated if metals are contaminants of concern.

C.5.4.1.3 Sampling procedure. The sampling procedure is as follows:

- Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination.
- C Sketch or photograph the sample area and note any recognizable features for future reference.
- C Insert scoop or trowel into material and remove sample.
- C Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as possible to the media. Refer to Instruction E-4 (Appendix E) for additional information on the collection, handling, and storage of solid VOC samples.
- C If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, the sample is transferred to a stainless steel bowl for mixing.
- C Repeat these steps as necessary to obtain sufficient sample volume.
- C Thoroughly mix remaining sample as outlined in Instructions E-2 and E-3 (Appendix E) as appropriate, collect suitable aliquots with a stainless steel laboratory spoon or equivalent, and transfer into an appropriate sample bottle.
- C Check that a PTFE liner is present in cap. Secure the cap tightly.
- C Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Place filled sample containers on ice immediately.

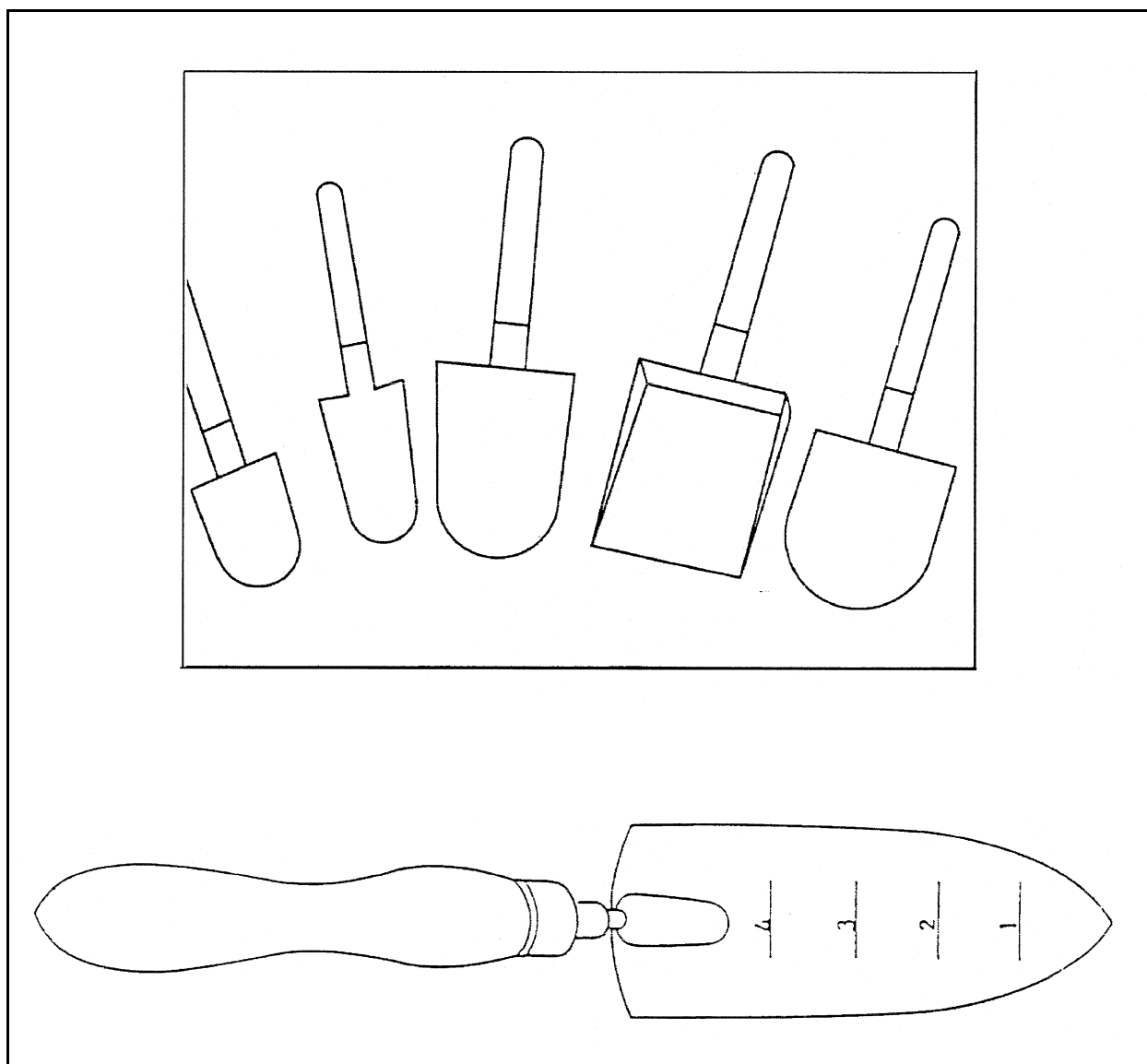


Figure C-10. Scoop trowel

- C Complete all chain-of-custody documents and field sheets and record in the field logbook (see Instruction F-1, “Documentation,” Appendix F).
- C Decontaminate sampling equipment after use and between sample locations.

C.5.4.2 Surface sediments/shallow water: Tube sampler. Method References: ASTM D 4700 and D 4823.

C.5.4.2.1 Applicability. Equipment for the tube sampler is portable and easy to use (Figure C-11). Discrete sediment samples can be collected efficiently. Disadvantages of the tube sampler include its inability to collect sediment samples in water bodies greater than a few feet in depth and its inability to penetrate gravelly or rocky sediments.

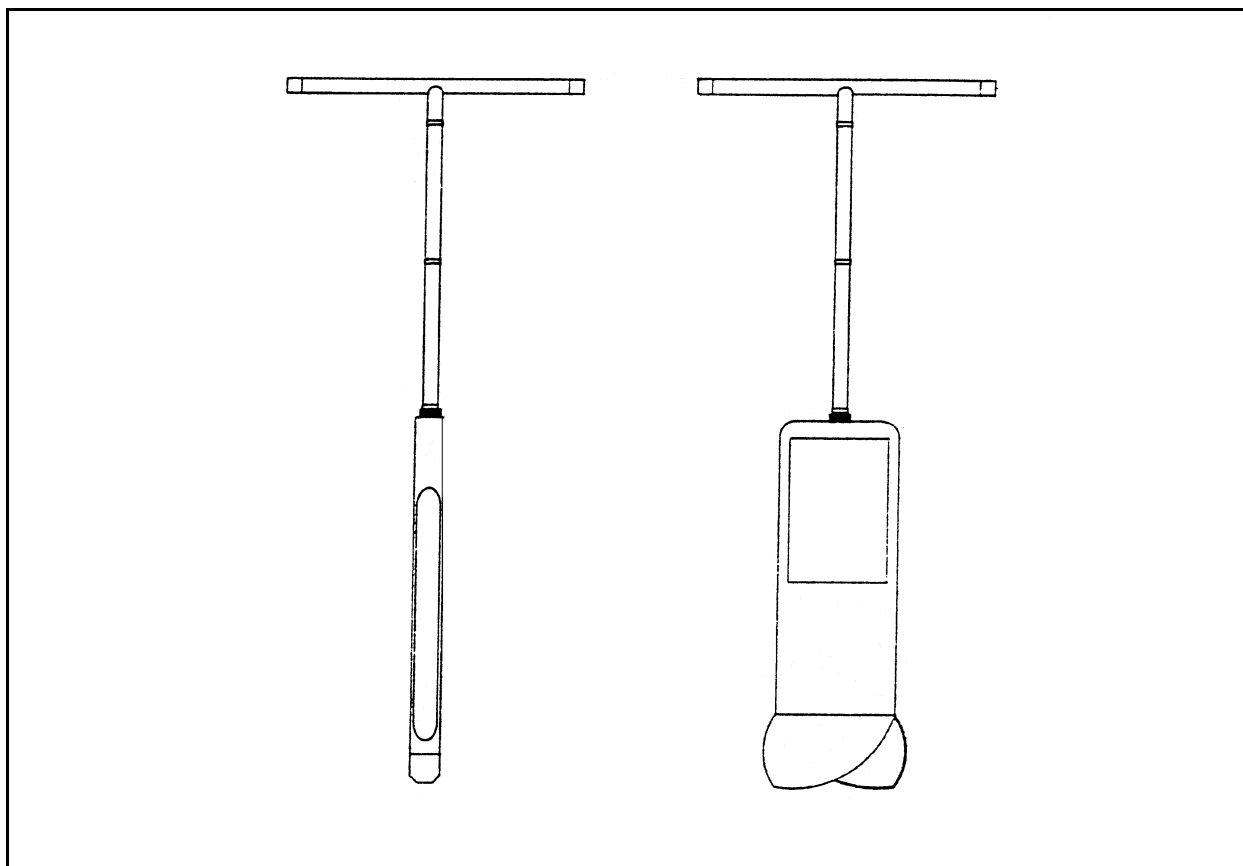


Figure C-11. Tube sampler and bucket auger

C.5.4.2.2 Method summary and equipment. Tube samplers are a simple and direct method for obtaining sediment samples. The tube sampler is forced into the sediment, then withdrawn and the sample is collected. In noncohesive soils, sample retention may be a problem.

C.5.4.2.3 Sampling procedure. The sampling procedure is as follows:

- C Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination. If access to sampling location is restricted, locate a boat, barge, or other stable working platform adjacent to the area to be sampled.
- C Sketch or photograph the sample area and note any recognizable features for future reference.
- C Gradually force tube sampler into sediment.
- C Carefully retrieve the tube sampler.
- C Remove sediment core from tube sampler and place core on a clean working surface.
- C Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as possible to the media. Refer to Instruction E-4 (Appendix E) for additional information on the collection, handling, and storage of solid VOC samples.

- C If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing.
- C Repeat these steps as necessary to obtain sufficient sample volume.
- C Thoroughly mix remaining sample as outlined in Instructions E-2 and E-3 as appropriate and collect suitable aliquots with a stainless steel laboratory spoon or equivalent, and transfer into an appropriate sample bottle.
- C Secure the cap tightly.
- C Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Place filled sample containers on ice immediately.
- C Complete all chain-of-custody documents and field sheets, and record in the field logbook (see Instruction F-1, Documentation).
- C Decontaminate sampling equipment after use and between sample locations.

C.5.4.3 Subsurface sediments/shallow water: Hand auger and tube sampler. Method Reference: ASTM D 1452.

C.5.4.3.1 Applicability. Equipment for the hand auger and tube sampler is portable and easy to use (Figures C-11 and C-12). Discrete sediment samples can be collected efficiently. Disadvantages of the hand auger include its inability to collect sediment samples in water bodies greater than a few feet in depth and its inability to penetrate gravelly or rocky sediments. Also, hand augers may not be an effective method for augering into very soft sediments since the borehole may collapse prior to sampling.

C.5.4.3.2 Method summary and equipment. Hand augers are a simple and direct method for obtaining sediment samples. Although the maximum sampling depth for the hand auger is typically 1.5 m (5 ft), greater depths can be sampled depending on the sediment type. Hand augers come in various dimensions and various types. The bucket auger bit is used to bore a hole to the desired sampling depth and is then withdrawn. The auger tip is then replaced with the tube sampler, which is lowered into the borehole and forced into the sediment at the

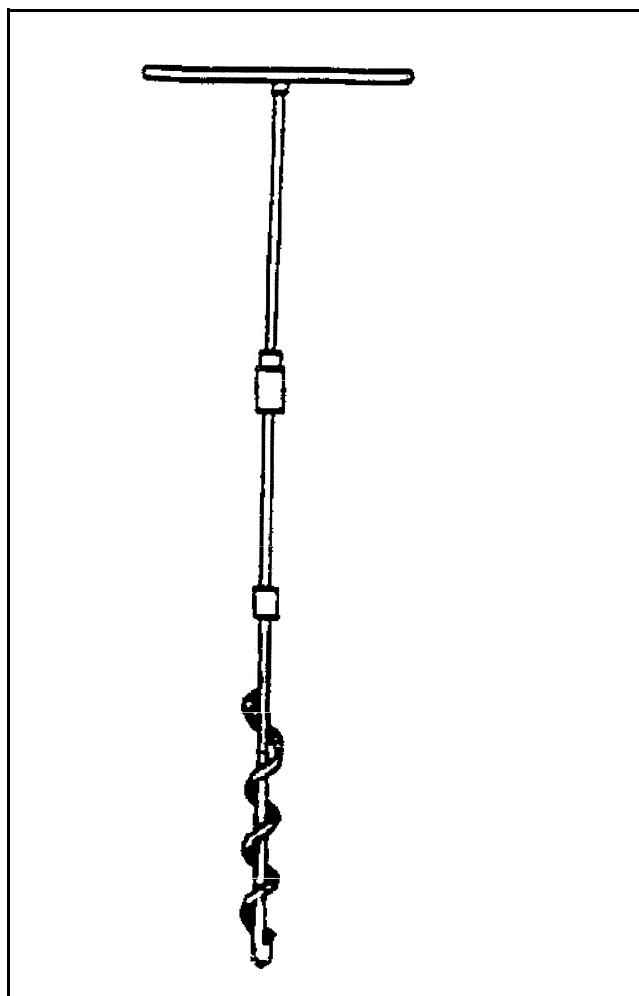


Figure C-12. Hand auger and tube sampler

desired depth. The corer is then withdrawn and the sample is collected. Potential problems encountered with this method include the collapsing or sloughing of the borehole after removal of the bucket auger. Relocating the borehole with the tube sampler may also be difficult if the water is turbid.

C.5.4.3.3 Sampling procedure. The sampling procedure is as follows:

- C Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination. If access to sampling location is restricted, locate a boat, barge, or other stable working platform adjacent to the area to be sampled.
- C Sketch or photograph the sample area and note any recognizable features for future reference.
- C Attach the auger bit to a drill rod extension and attach the T-handle to the drill rod.
- C Begin drilling. Periodically remove accumulated sediment to prevent accidentally brushing loose material into the borehole when removing the auger.
- C After reaching the desired depth, slowly and carefully remove the auger from boring.
- C Remove the auger tip from drill rods and replace with a precleaned or decontaminated thin-wall tube sampler. Install proper cutting tip.
- C Carefully lower the tube sampler down borehole, and gradually force it into the sediment. Take care to avoid scraping the borehole sides. Avoid hammering the drill rods to facilitate coring because the vibrations may cause the boring wall to collapse.
- C Carefully retrieve the tube sampler and unscrew drill rods.
- C Remove cutting tip and remove core from device.
- C Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as possible to the media. Refer to Instruction E-4 for additional information on the collection, handling, and storage of solid VOC samples.
- C If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing.
- C Repeat these steps as necessary to obtain sufficient sample volume.
- C Thoroughly mix remaining sample as outlined in Instructions E-2 and E-3 as appropriate, collect suitable aliquots with a stainless steel laboratory spoon or equivalent, and transfer into an appropriate sample bottle.
- C Secure the cap tightly.
- C Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Place filled sample containers on ice immediately.

- C Complete all chain-of-custody documents and field sheets, and record information in the field logbook (see Instruction F-1, "Documentation," Appendix F).
- C Decontaminate sampling equipment after use and between sample locations.

C.5.4.4 Subsurface sediments/shallow water: Hand-driven split-spoon core sampler.

C.5.4.4.1 Applicability. The split-spoon core sampler may be used for obtaining sediment samples in cohesive and noncohesive sediments. Similar to the hand auger, the hand-driven split-spoon sampler can be used only in shallow water. However, because it is hammered into place, it can sometimes penetrate sediments that are too hard to sample with a hand auger.

C.5.4.4.2 Method summary and equipment. The split-spoon sampler is a 50.8-mm- (2-in.) diam, thick-walled, steel tube that is split lengthwise (Figure C-13). A cutting shoe is attached to the lower end; the upper end contains a check valve and is connected to the drill rods. For sediment sampling, the split-spoon sampler is usually attached to a short driving rod and driven into the sediment with a sledge hammer or slide hammer to obtain a sample.

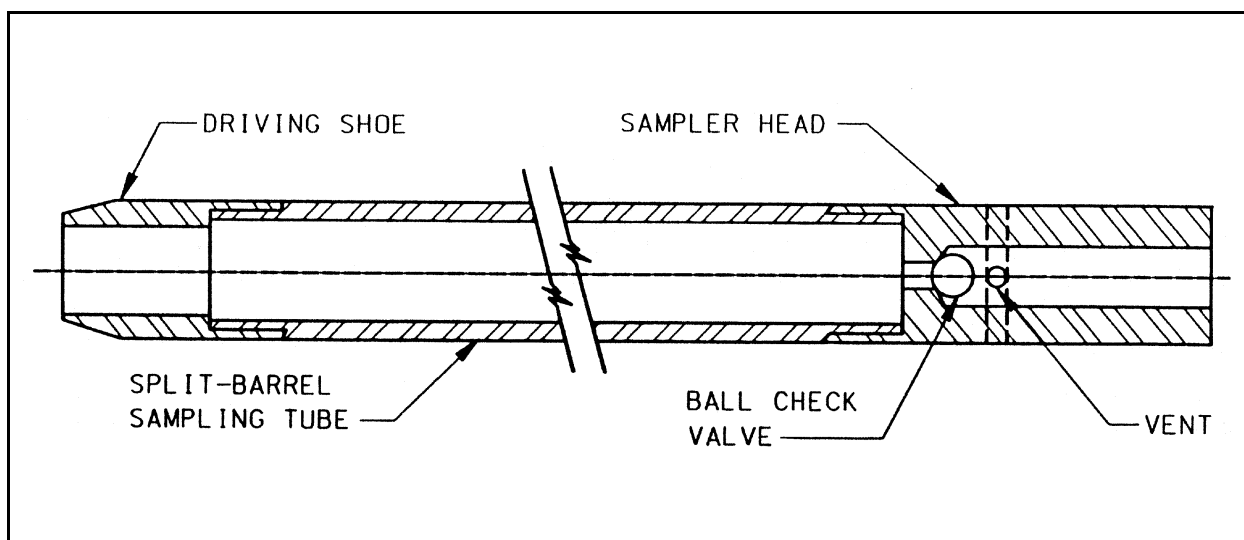


Figure C-13. Standard split-spoon sampler

C.5.4.4.3 Sampling procedure. The sampling procedure is as follows:

- C Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination. If access to sampling location is restricted, locate a boat, barge, or other stable working platform upstream to the area to be sampled.
- C Sketch or photograph the sample area and note any recognizable features for future reference.
- C Assemble the sampler by aligning both sides of barrel and then screwing the drive shoe on the bottom and the heavier headpiece on top.
- C Lower the sampler into position perpendicular to the material to be sampled.

- C Drive the tube into the sediments with a sledge hammer. Do not drive past the bottom of the headpiece as this will result in compression of the sample.
- C Withdraw the sampler and open by unscrewing drive shoe, head, and splitting barrel. If split samples are desired, use a decontaminated stainless steel knife to split the tube contents in half longitudinally.
- C Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as possible to the media. Refer to Instruction E-4 for additional information on the collection, handling, and storage of solid VOC samples.
- C If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing.
- C Repeat these steps as necessary to obtain sufficient sample volume.
- C Thoroughly mix remaining sample as outlined in Instructions E-2 and E-3 as appropriate, collect suitable aliquots with a stainless steel laboratory spoon or equivalent, and transfer into an appropriate sample bottle.
- C Secure the cap tightly.
- C Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Place filled sample containers on ice immediately.
- C Complete all chain-of-custody documents and field sheets, and record information in the field logbook (see Instruction F-1, "Documentation," Appendix F).
- C Decontaminate sampling equipment after use and between sample locations.

C.5.4.5 Surface sediments/deep water: Ponar sampler. Method References: ASTM D 4342 and EPA/540/P-91/005, SOP #2016.

C.5.4.5.1 Applicability. Ponar samplers are capable of sampling most types of sludges and sediments from silts to granular materials. They are available in hand-operated sizes to winch-operated sizes. Ponars are relatively safe and easy to use, prevent escape of material with end plates, reduce shock waves, and have a combination of the advantages of other sampling devices. Ponar samplers are more applicable for a wide range of sediments and sludges because they penetrate deeper and seal better than spring-activated types (e.g., Ekman samplers). Penetration depths will usually not exceed several centimeters in sand. Greater penetration is possible in fine-grained material, up to the full depth of the sampler for soft sediments. Ponar samplers are not capable of collecting undisturbed samples. As a result, material in the first centimeter of sediment cannot be separated from the rest of the sample. Ponars can become buried in soft sediment.

C.5.4.5.2 Method summary and equipment. The Ponar sampler is a clamshell-type scoop activated by a counter-lever system (Figure C-14). The shell is opened, latched in place, and slowly lowered to the bottom. When tension is released on the lowering cable, the latch releases and the lifting action of the cable on the lever system closes the clamshell.

C.5.4.5.3 Sampling procedure. The sampling procedure is as follows:

- C Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination. If access to sampling location is restricted, locate a boat, barge, or other stable working platform upstream of the area to be sampled.
- C Sketch or photograph the sample area and note any recognizable features for future reference.
- C Attach a decontaminated Ponar to the necessary length of sample line. Solid braided 5-mm (3/16-in.) nylon line is usually of sufficient strength; however, 20-mm (3/4-in.) or greater nylon line allows for easier hand hoisting.
- C Measure the depth to the top of the sediment with a weighted object.
- C Mark the distance to the top of the sediment on the sample line with a proximity mark 1 m above the sediment. Record depth to top of sediment and depth of sediment penetration.

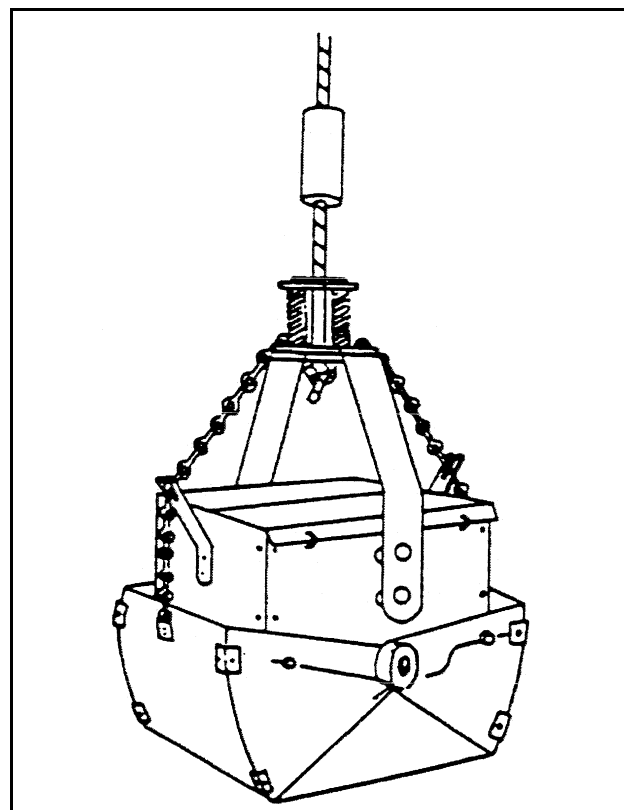


Figure C-14. Ponar sampler

- C Open sampler jaws until latched. From this point, support the sampler by its lift line, or the sampler will be tripped and the jaws will close.
- C Tie the free end of sample line to fixed support to prevent accidental loss of sampler.
- C Begin lowering the sampler until the proximity mark is reached.
- C Lower the sampler at a slow rate of descent through last meter until contact is felt.
- C Allow sample line to slack several centimeters. In strong currents, more slack may be necessary to release mechanism.
- C Slowly raise Ponar grab sampler to clear surface.
- C Drain free liquids through the screen of the sampler, being careful not to lose fine sediments.
- C Place Ponar into a stainless steel or PTFE tray and open. Lift Ponar clear of the tray, and set aside for decontamination.

- C Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as possible to the media. Samples should be taken from the center of the mass of sediment, avoiding material that has come in contact with the walls of the sampler. Refer to Instruction E-4 for additional information on the collection, handling, and storage of solid VOA samples.
- C Repeat these steps until sufficient sample volume has been collected for remaining parameters.
- C If compositing of different locations is desired, transfer additional discrete samples to a stainless steel bowl for mixing.
- C Thoroughly mix remaining sample as outlined in Instructions E-2 and E-3 as appropriate, collect suitable aliquots with a stainless steel laboratory spoon or equivalent, and transfer into an appropriate sample bottle.
- C Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Place filled sample containers on ice immediately.
- C Complete all chain-of-custody documents and field sheets and record information in the field logbook (see Instruction F-1, "Documentation," Appendix F).
- C Decontaminate sampling equipment after use and between sample locations.

C.5.4.6 Surface sediments/deep water: Ekman grab sampler. Method References: ASTM D 4343 and EPA/540/P-91/005, SOP #2016.

C.5.4.6.1 Applicability. The Ekman sampler collects a standard size sample. The Ekman sampler is not useful in rough waters or if vegetation is on the bottom.

C.5.4.6.2 Method summary and equipment. The Ekman sampler (Figure C-15) is another clamshell-type grab sampler and works similarly to the Ponar sampler described previously. However, because the Ekman sampler is much lighter than the Ponar sampler, it is easier to handle and can even be attached to a pole for shallow applications. The Ekman sampler is unsuitable for sampling rocky or hard bottom surfaces.

C.5.4.6.3 Sampling procedure. The sampling procedure is as follows:

- C Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination. If access to

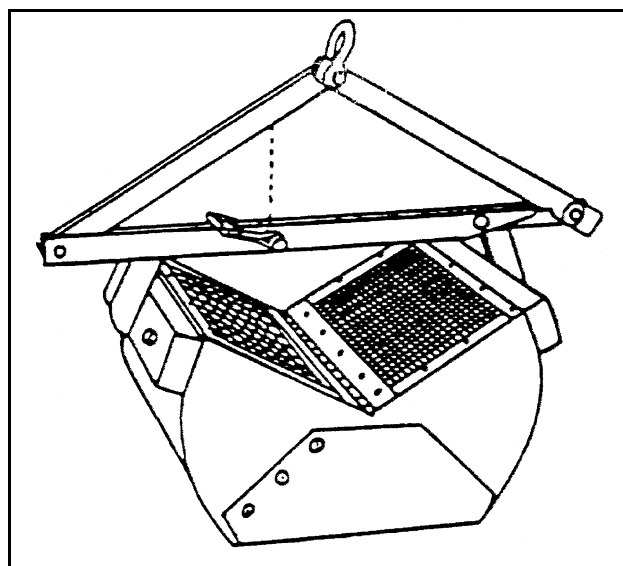


Figure C-15. Ekman sampler

sampling location is restricted, locate a boat, barge, or other stable working platform upstream of the area to be sampled.

- C Sketch or photograph the sample area and note any recognizable features for future reference.
- C Attach a decontaminated Ekman sampler to the necessary length of sample line or in shallow waters to the end of a pole. Because the Ekman sampler is lightweight, solid braided 5-mm (3/16-in.) mylar line is sufficient.
- C Measure the depth to the top of the sediment with a weighted object. Record the depth to top of sediment.
- C Mark the distance to top of sediment on the sample line and add a proximity mark 1 m above the first mark so that the person taking the sample will know when he is approaching sediment.
- C Open sampler jaws until latched. From this point, support the sampler by its lift line, or the sampler will be tripped and the jaws will close.
- C If using a sample line, tie the free end of the sample line to fixed support to prevent accidental loss of sampler.
- C Begin lowering the sampler until the proximity mark is reached.
- C Lower the sampler at a slow rate of descent through the last meter until contact is felt.
- C If using a sample line, place a messenger on the sample line and release, allowing the messenger to slide down to the sample line and activate the spring. Record the depth of sediment penetration by the sampler.
- C Slowly raise Ekman grab sampler to clear surface.
- C Drain free liquids through the screen of the sampler, being careful not to lose fine sediments.
- C Place Ekman sampler into a stainless steel or PTFE tray and open. Lift Ekman sampler clear of the tray and set aside for decontamination.
- C Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as possible to the media. Samples should be taken from the center of the mass of sediment, avoiding material that has come in contact with the walls of the sampler. Refer to Instruction E-4 for additional information on the collection, handling, and storage of solid VOA samples.
- C Repeat these steps until sufficient sample volume has been collected for remaining parameters.
- C If compositing of different locations is desired, transfer additional discrete samples to stainless steel bowl for mixing.

- C Thoroughly mix remaining sample as outlined in Instructions E-2 and E-3 as appropriate, collect suitable aliquots with a stainless steel laboratory spoon or equivalent, and transfer into an appropriate sample bottle.
- C Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Place filled sample containers on ice immediately.
- C Complete all chain-of-custody documents and field sheets and record information in the field logbook (see Instruction F-1, "Documentation," Appendix F).
- C Decontaminate sampling equipment after use and between sample locations.

C.5.4.7 Surface sediment/deep water: Smith-McIntyre grab sampler. Method Reference: ASTM D 4344.

C.5.4.7.1 Applicability. The Smith-McIntyre grab sampler can be used in rough water because of its large and heavy construction. It reduces premature tripping and can be used in depths up to 1,050 m (3,500 ft). The flange on the jaws reduces material loss. It is good for sampling all sediment types. However, because of its large and heavy construction, the Smith-McIntyre sampler is cumbersome to operate.

C.5.4.7.2 Method summary and equipment. The Smith-McIntyre grab sampler (Figure C-16) is also a type of clam-shell-style grab sampler and works similarly to the Ponar sampler described previously.

C.5.4.7.3 Sampling procedure. The sampling procedure is as follows:

- C Spread new plastic sheeting on the deck of a boat or barge to keep sampling equipment decontaminated and to prevent cross-contamination.
- C Sketch or photograph the sample area and note any recognizable features for future reference.

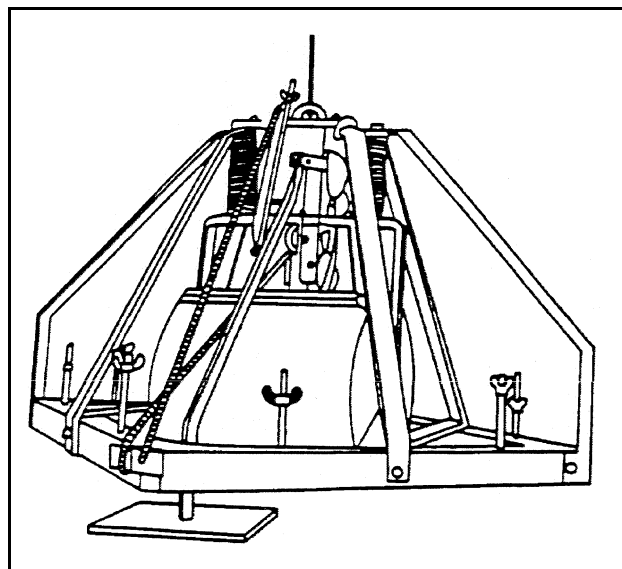


Figure C-16. Smith-McIntyre sampler

- C Attach a decontaminated Smith-McIntyre sampler to the necessary length of sample line. Because the Smith-McIntyre sampler is large and heavy, a winch should be used for hoisting and lowering the sampler.
- C Measure the depth to the top of the sediment with a weighted object.
- C Mark the distance to top of sediment on the sample line with a proximity mark 2.5 cm (1 in.) above the sediment. Record depth to top of sediment and depth of sediment penetration.

- C Open sampler jaws until latched. From this point, support the sampler by its lift line, or the sampler will be tripped and the jaws will close.
- C If using a sample line, tie the free end of sample line to fixed support to prevent accidental loss of sampler.
- C Begin lowering the sampler until the proximity mark is reached.
- C Lower the sampler at a slow rate of descent through last meter until contact is felt.
- C Allow sample line to slack several centimeters. In strong currents, more slack may be necessary to release mechanism.
- C Slowly raise Smith-McIntyre grab sampler to clear surface.
- C Drain free liquids through the screen of the sampler, being careful not to lose fine sediments.
- C Place Smith-McIntyre sampler into a stainless steel or PTFE tray and open. Lift Smith-McIntyre sampler clear of the tray and set aside for decontamination.
- C Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as possible to the media. Samples should be taken from the center of the mass of sediment, avoiding material that has come in contact with the walls of the sampler. Refer to Instruction E-4 for additional information on the collection, handling, and storage of solid VOA samples.
- C Repeat these steps until sufficient sample volume has been collected for remaining parameters.
- C If compositing of different locations is desired, transfer additional discrete samples to stainless steel bowl for mixing.
- C Thoroughly mix remaining sample as outlined in Instructions E-2 and E-3 as appropriate, collect suitable aliquots with a stainless steel laboratory spoon or equivalent, and transfer into an appropriate sample bottle.
- C Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Place filled sample containers on ice immediately.
- C Complete all chain-of-custody documents and field sheets and record information in the field logbook (see Instruction F-1, "Documentation," Appendix F).
- C Decontaminate sampling equipment after use and between sample locations.

C.5.4.8 Subsurface sediments/deep water: Gravity and piston corers. Method References: EM 1110-1-1906, ASTM D 4823, Mudroch and MacKnight (1991), and American Public Health Association (1995).

C.5.4.8.1 Applicability. Gravity corers are capable of collecting samples of most sludges and sediments. They collect essentially undisturbed samples that represent the profile of strata that may develop in sediments and sludges during variations in the deposition process. The gravity corer may be limited to cores of 1 to 2 m (3 to 6.5 ft) in depth, depending on sediment grain size, degree of sediment compaction, and velocity of the drop. Because gravity corers can compact the sample and distort the vertical profile, a vibratory corer is recommended to minimize sample compaction and when vertical stratification in a core sample is of interest. If the samples will not be sectioned prior to analysis and compaction is not a problem, the gravity (free-fall) corers may be the simplest alternative. The piston corer is similar to a gravity corer but also has a piston inside the tube that remains stationary during sediment penetration and creates a vacuum that helps pull the sampler into the sediment. The piston corer uses both gravity and hydrostatic pressure. Refer to Figure C-20 within Instruction C-6 for a schematic of a piston corer (sampler). As the cutting edge of the corer penetrates the sediments, an internal piston remains at the level of the sediment/water interface, preventing sediment compression and overcoming internal friction.

C.5.4.8.2 Method summary and equipment. The gravity corer uses weights attached to the head of the sampling tube to push the tube into the sediment. It is a metal tube with a replaceable tapered nosepiece on the bottom and a ball or other type of check valve on the top. The check valve allows water to pass through the corer on descent but prevents a washout during recovery. The tapered nosepiece facilitates cutting and reduces core disturbance during penetration. Most corers are constructed of brass or steel, and many can accept plastic liners and additional weights.

C.5.4.8.3 Sampling procedure. The sampling procedure is as follows:

- C Spread new plastic sheeting on the ground at each sampling location to keep sampling equipment decontaminated and to prevent cross-contamination. If access to sampling location is restricted, locate a boat, barge, or other stable working platform upstream of the area to be sampled.
- C Sketch or photograph the sample area and note any recognizable features for future reference.
- C Attach a decontaminated corer to the required length of sample line. Solid braided 5-mm (3/16-in.) nylon line is typically sufficient; 20-mm (3/4-in.) nylon, however, is easier to grab during hand hoisting.
- C Secure the free end of the line to a fixed support to prevent accidental loss of the corer.
- C Allow corer to free fall through liquid to bottom.
- C Retrieve corer with a smooth, continuous lifting motion. Do not bump corer as this may result in some sample loss.
- C Remove nosepiece from corer and slide sample out of corer into stainless steel or PTFE pan.
- C Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as possible to the media. Refer to Instruction E-4 for additional information on the collection, handling, and storage of solid VOA samples.
- C Repeat these steps until sufficient sample volume has been collected for remaining parameters.
- C If compositing of different locations is desired, transfer additional discrete samples to stainless steel bowl for mixing.

- C Thoroughly mix remaining sample as outlined in Instructions E-2 and E-3 as appropriate, collect suitable aliquots with a stainless steel laboratory spoon or equivalent, and transfer into an appropriate sample bottle.
- C Check that a liner is present in cap. Secure the cap tightly.
- C Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Place filled sample containers on ice immediately.
- C Complete all chain-of-custody documents and field sheets and record information in the field logbook (see Instruction F-1, "Documentation," Appendix F).
- C Thoroughly decontaminate the gravity corer after each use.

C.5.4.9 Subsurface sediments/deep water: Vibratory coring device.

C.5.4.9.1 Applicability. Vibratory corers are capable of collecting samples of most soils, sediments, and sludges. For penetration greater than 2 m (6.5 ft), a vibratory corer is generally preferred.

C.5.4.9.2 Method summary and equipment. The vibratory system consists of a tripod that supports a core tube. An external power source is necessary to drive a top head and cause vibrations. The vibratory motion causes the soil sediments to become fluidized and the core tube to slip through the soil or sediment. It is capable of obtaining 3- to 7-m cores in a wide range of sediment types by vibrating a large diameter core barrel through the sediment column with little compaction. For additional information, see EM 1110-1-1906, Finkelstein and Prins (1981), Meisburger and Williams (1981), U.S. Army Engineer Waterways Experiment Station (1982), and Smith (1993).

C.5.4.9.3 Sampling procedure. The sampling procedure is as follows:

- C Locate a boat, barge, or other stable working platform over the area to be sampled.
- C Sketch or photograph the sample area and note any recognizable features for future reference.
- C Assemble a decontaminated vibratory corer and connect an external power source (i.e., air compressor).
- C Attach decontaminated corer to the required length of sample line to reach the top of the soil or sediment.
- C Lower the corer down to the top of sediments and begin vibratory coring until the core tube has fully penetrated.
- C Carefully retrieve the core tube and remove the core liner.
- C Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as possible to the media. Refer to Instruction E-4 for additional information on the collection, handling, and storage of solid VOA samples.

- C If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing.
- C Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Thoroughly mix remaining sample as outlined in Instructions E-2 and E-3 as appropriate, collect suitable aliquots with a stainless steel laboratory spoon or equivalent, transfer into an appropriate sample bottle, secure cap tightly, and put the container on ice.
- C Complete all chain-of-custody documents and field sheets and record information in the field logbook (see Instruction F-1, "Documentation," Appendix F).
- C Thoroughly decontaminate the vibratory corer after each use.

C.5.4.10 Subsurface sediments/deep water: Box core sampler.

C.5.4.10.1 Applicability. The corer that disturbs the sediments the least is a box corer. One advantage of the box corer is its ability to collect a large amount of sample with the center of the sample virtually undisturbed. Box corers are not generally recommended for use in sandy sediments since they have difficulty retaining the sample upon withdrawal.

C.5.4.10.2 Method summary and equipment. The box corer is a large box-shaped sampler that is deployed inside a frame. After the frame is brought to rest on the bottom, heavy weights lower the open-ended box into the sediment. A bottom door then swings shut upon retrieval to prevent sample loss.

C.5.4.10.3 Sampling procedure. The sampling procedure is as follows:

- C Locate a boat, barge, or other stable working platform over the area to be sampled.
- C Sketch or photograph the sample area and note any recognizable features for future reference.
- C Assemble decontaminated box corer into the sample frame.
- C Attach decontaminated box corer and frame to the required length of sample line, cable, or rope to reach the top of the soil or sediment.
- C Secure the free end of the line to a fixed support to prevent accidental loss of the corer, if applicable.
- C Lower the box corer and frame down to the sediments. Weights will force the box corer into the sediments for sample collection.
- C Carefully retrieve the box corer with a smooth, continuous lifting motion. The box bottom will swing shut upon retrieval.
- C Open the bottom lid to remove sample out of corer into stainless steel or PTFE pan.

- C Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as possible to the media. Refer to Instruction E-4 for additional information on the collection, handling, and storage of solid VOA samples.
- C Repeat these steps until sufficient sample volume has been collected for remaining parameters.
- C If compositing of different locations is desired, transfer additional discrete samples to a stainless steel bowl for mixing.
- C Thoroughly mix remaining sample as outlined in Instructions E-2 and E-3 as appropriate, collect suitable aliquots with a stainless steel laboratory spoon or equivalent, transfer into an appropriate sample bottle.
- C Check that a liner is present in cap. Secure the cap tightly.
- C Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Place filled sample containers on ice immediately.
- C Complete all chain-of-custody documents and field sheets and record information in the field logbook (see Instruction F-1, "Documentation," Appendix F).
- C Thoroughly decontaminate the box corer after each use.

C.5.5 Decontamination procedures. All equipment that will enter the sediment must be decontaminated as described in Instruction E-6 (Appendix E). Sampling equipment should be placed in plastic bags until immediately prior to use. Additional sampling devices may be needed onsite to ensure an adequate drying time.

C.5.6 Field control sample requirements. Field control samples are collected by the sampling team to determine whether the data are of suitable quality. They include blanks, replicates, and/or background samples. QA samples are replicates sent to a referee (QA) laboratory and analyzed to evaluate the contractor's laboratory performance. QC samples are blind replicates collected by the sampling team for analysis by the primary laboratory. A detailed discussion of field control samples is contained in Instruction G-2 (Appendix G).

C.5.7 Documentation requirements. Bound field logbooks should be used for the maintenance of field records. Record all aspects of the site setup, sample collection, and handling as outlined previously and in Instruction F-1, Appendix F.

C.5.8 Analytical techniques for sediment samples. Techniques for chemical analysis of sediments have some inherent limitations. Interferences encountered as part of the sediment matrix, particularly in samples from heavily contaminated areas, may limit the ability of a method to detect or quantify some analytes at the required levels. Sediment analyses usually require lower reporting limits than for soils because regulatory or effects levels are, in general, lower in sediments than in soil. These lower reporting levels may require a change in calibration of analytical instrumentation using lower concentration standards. Lower spiking concentrations will probably be required to better represent the recoveries in low concentration samples. For many metals analyses in marine/estuarine areas, the concentration of salt may

be much greater than the analyte of interest and can cause unacceptable interference in certain analytical techniques. For this reason and the need for lower detection limits, analytical methods for soils may need to be modified or different methods selected. The analyses for semivolatile and VOCs may also need to be modified to achieve lower detection limits and cleanup of this complex matrix. Extensive cleanup is required because of the likely presence of biological macromolecules, which accumulate in sediments; sulfur from sediments with low or no oxygen; and oil and/or grease in the sediment. In addition to all of the previously stated differences between soil and sediment analyses, sediments may require the analysis for other constituents. For example, knowing the concentration of TOC is important for evaluating the bioavailability of neutral organics (i.e. PAH's, PCB's, dioxin, and chlorinated pesticides). In areas with marinas or high ship and boat use, it may be necessary to analyze the sediment for tri-butyl tin (TBT), a highly toxic and persistent component of antifouling paint.

C.6 Soil Sampling

C.6.1 Scope and application. This instruction presents guidance for collecting representative soil samples. Soil sampling can be classified into two primary types: surface and subsurface. Instructions for sampling surface and subsurface soils by the following techniques are included in this instruction: spade and scoop, hand auger and tube sampler, split-spoon sampler, ring-lined barrel sampler, thin-walled (Shelby) tube, continuous tube sampler, piston sampler, core barrel sampler, direct push, and site characterization and analysis penetrometer system (SCAPS). EM 1110-1-1906 also addresses these and other types of geotechnical soil sampling, which may be adapted for environmental purposes.

C.6.2 Sampling strategies. Sampling strategies are developed by the project team to satisfy project-specific data needs that are identified in the HTRW technical planning process. The sampling strategy developed for a particular site will influence several project decisions, including, but not limited to, sampling locations, sample depths, types of samples, sampling frequency, and sampling and analytical protocols. Clarification of key definitions may need to be addressed. For instance, surface soils should be defined in terms of depth requirements. For depending on the data use, surface soils may be defined as the 0-5 cm (0-2 inch), or the 0-15 cm (0-6 inch) depth interval. Sampling strategies may also be significantly influenced by such factors as matrix and contaminant characteristics, physical site constraints, safety, and cost, to name a few. Soil sampling pose a variety of challenges due to the natural variability of the media, the lack of understanding of contaminant migration through the vadose zone, and the logistical problems of sampling at increased depths. Additionally, the particle size distribution of the soils must be evaluated against the scale of the contaminant. Contaminants present on a macro-scale (i.e., lead shot, solid contaminant material or chunks) is more susceptible to bias during sampling procedures, than contaminants found on a molecular scale. The technical planning process that results in the development of the sampling strategy is critical because of these difficulties in acquiring representative samples, the reduction of contaminant action levels, and the problems associated with trace level cross-contamination. Development of a sampling scheme to characterize a hazardous waste site should follow the fundamentals of scientific approach. A successful sampling scheme requires a logical design to allow an evaluation of potential contaminants in relation to background conditions, vertical extent, horizontal extent, and mobility in various media.

C.6.2.1 Sampling locations. Sampling at hazardous waste sites is usually conducted in an attempt to discover contamination and to define its extent and variability. With such an objective, it is most logical to choose sample locations that will yield the most information about site conditions. During evaluation of a site, sampling can be conducted by random, systematic, or biased sampling. Biased samples are those collected at locations that were chosen based on historical information, knowledge about the behavior of the contaminant(s), and/or knowledge about the effects of the physical system on the fate of the contaminant. Random sampling depends on the theory of random chance probabilities to choose the most representative sample. Often, biased and random sampling techniques can be used together to thoroughly address an entire site. Some samples may be biased to potentially contaminated areas (e.g., stained soil, former process or disposal areas) or potentially impacted areas (e.g., areas of stressed vegetation). In areas less likely to be contaminated or areas with little available background information, random samples may be used to allow adequate assessment of the entire site. Because of the nature of the media, soil samples can vary considerably across a site. Physical properties of the soil, including grain size and cohesiveness, may limit the depth from which samples can be collected and the method required to collect them. In most soils, hand-powered equipment can be used only to a depth of approximately 120 to 150 cm (4 to 5 ft). At greater depths, soil sampling is normally performed with a drill rig or other mechanically driven device.

C.6.2.2 Types of samples. The type of sample should be designated when selecting a sampling method. Application techniques for sample methods include discrete (grab) or composite samples. A

discrete (grab) sample is defined as a discrete aliquot representative of a specific location at a given point in time. The sample is collected immediately and at one particular point in the sample matrix. The representativeness of such samples is defined by the nature of the materials being sampled. In general, as sources vary over time and distance, the representativeness of grab samples will decrease. Composites are samples composed of two or more specific aliquots (discrete samples) collected at various sampling locations or depths. Analysis of this type of sample produces an average value and can, in certain instances, be used as an alternative to analyzing a number of individual grab samples and calculating an average value. It should be noted, however, that compositing can mask the presence of contaminants by diluting isolated concentrations of analytes that may be present in the environmental matrix. Samples can be collected manually if soil conditions are favorable and the desired depth of sampling is not too great. Manual sampling involves minimal initial cost, and the method is well suited to a relatively small or specific number of samples. At depths greater than 120 to 150 cm (4 to 5 ft), manual sampling will probably not be possible, and a mechanically driven drilling device will be required. Depending on the sampling requirements of the site, the use of a mechanical drilling device can substantially increase the cost of a sampling investigation. However, it is usually the only method available to obtain soil samples at depths greater than a few feet. There are a great variety of mechanical drilling devices available for soil sampling. Discussions concerning the use of mechanical drilling devices will be limited to the actual tools used to collect the soil samples.

C.6.2.3 Suggested samplers. Each sampling technique presents various disadvantages and advantages for its application. For example, sample disturbance, sample volume, chemical/physical reactivity between potential contaminants and sampling tool materials, and ease of decontamination varies from technique to technique. Subsurface soil conditions themselves will restrict the application of certain samplers. For example, the thin-walled tube sampler is not applicable for sampling sands. Discussions of the advantages and disadvantages of each sampling technique are presented in the following sections.

C.6.2.4 Sample frequency. Determination of the number of samples needed to characterize a site also depends on the objectives and the site-specific conditions. For example, if the objective of the event is to determine whether the site is contaminated, a limited number of samples from properly chosen locations will yield useful information. If, however, the site is known to be contaminated and delineation of the contamination is the objective, a greater number of samples may be needed. In many cases statistical considerations can be helpful in determining sampling strategy. Additional guidance concerning sample frequency can be found in other U.S. Army Corps of Engineers (USACE) guidance and in ASTM D 5911, D5254, and D5792.

C.6.3 Sample preservation and handling. Many of the chemical constituents and physicochemical parameters that are to be measured or evaluated in soil investigation programs are not chemically stable; therefore, sample preservation is required. Appropriate preservation techniques for various parameters are specified in Appendix B. In addition, sample containers that the sampler should use for each constituent or common set of parameters are specified in Appendix B. These preservation methods and sample containers are based on EPA/SW-846. Procedures and techniques for transporting the samples to the offsite laboratory are discussed in Instruction F-2, "Packaging and Shipping Procedures," Appendix F. Improper sample handling may alter the analytical results of the sample, causing the results to be invalid. When subsequent analysis allows, soil samples should be collected using a clean stainless steel scoop, spoon, or trowel and placed into clean stainless steel or other appropriate homogenization containers. Homogenization procedures are discussed in Instruction E-2, Appendix E. The sample should be mixed thoroughly to obtain a homogeneous, representative sample prior to placement into the sample container. When composited samples from different locations or depths are desired, all components of the composite sample are mixed in the homogenization container before the composite is placed in the sample container. Compositing procedures are discussed in Instruction E-3, Appendix E. The sample should then be preserved in the field as specified in Appendix B. Because of the low analytical detection limits that are required for certain data

uses, care must be taken when collecting the sample to avoid the loss or gain of any contaminants. For example, the samples packaged for volatile analysis should not be homogenized or composited. They should be handled in a manner as outlined in Instruction E-4, "Collection, Handling, and Storage of Solid Samples for VOC Analysis" in order to minimize contaminant loss through agitation/ volatilization.

C.6.3.1 Sample containers. When metals are the analytes of interest, wide-mouth glass jar containers with PTFE-lined polypropylene caps should be used. When organics are the analytes of interest, glass bottles with PTFE-lined caps should be used. Refer to Appendix B or the specific analytical method to designate an acceptable container. Containers should be cleaned based on the analyte of interest. Instruction E-6, "Decontamination Procedures," contains additional information on appropriate glassware cleaning protocols. If precleaned bottles are used, the cleanliness of each lot of precleaned bottles should be verified by the container supplier or in the laboratory and appropriate paperwork (i.e., certificates) retained with other field documentation. Refer to Appendix B or the specific analytical method for information on the required size and type of sample containers. Samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. A preferred collection order for some common parameters follows:

- VOA
- POC
- POX
- TOX
- TOC
- Extractable organics
- Total metals
- Cyanide
- Sulfate and chloride
- Nitrate and ammonia
- Radionuclides

C.6.3.2 Sample preservation. Methods of sample preservation are relatively limited and are generally intended to retard biological action and hydrolysis and to reduce sorption effects. Preservation methods for soil samples are dependant on the type of analyses. For nonvolatile analysis, sample preservation is generally limited to refrigeration and/or protection from light. Volatile soil sample preservation is based on whether analysis is to be low-level or medium-level analysis. Refer to Instruction E-4, Appendix E, for details. The sampler should refer to Appendix B or the specific preservation method in EPA/SW-846 for the appropriate preservation technique.

C.6.3.3 Special handling for VOA samples. Samples to be analyzed for purgeable organic compounds should be acquired as described in Instruction E-4 of Appendix E, "Collection, Handling, and Storage of Solid Samples for VOC Analysis."

C.6.3.4 Special precautions for trace contaminant sampling. Contaminants can be detected in the parts per billion and/or parts per trillion ranges. Therefore, extreme care must be taken to prevent cross-contamination of these samples. The following general precautions should be taken when sampling:

- A clean pair of new, disposable gloves should be worn each time a different location is sampled and gloves should be donned immediately prior to sampling.
- All work should be conducted on a clean surface, such as a stainless steel table.
- To prevent cross-contamination between samples, it is suggested that the multiple vials from each sampling location be sealed in separate smaller plastic bags when the sampled medium is suspected of containing high concentrations of volatile organics.
- Sample containers filled with source or waste samples or samples suspected of containing high concentrations of contaminants should be placed in separate plastic bags immediately after collecting and preserving, and activated carbon should be included in the bags to prevent cross-contamination.
- If possible, background samples and source samples should be collected by different field teams. If different field teams cannot be used, all background samples should be collected first and placed in separate ice chests or shipping containers. Samples of waste or highly contaminated samples should never be placed in the same ice chest as environmental samples. It is good practice to enclose waste or highly contaminated samples in a plastic bag before placing them in ice chests. Ice chests or shipping containers for source samples or samples suspected to contain high concentrations of contaminants should be lined with new, clean, plastic bags.
- If possible, one member of the field team should take all the notes, fill out sample tags, field sheets, etc., while the other members collect all of the samples. This is especially important when subjective decisions such as soil type and descriptions are being made.
- Sample collection activities should proceed progressively from the suspected least contaminated area to the suspected most contaminated area.
- Field personnel should take precautions to prevent contamination from sampling equipment. Most soil samplers are constructed of metal. Stainless steel samplers are preferable. All samplers should be properly decontaminated and inspected for visible signs of deterioration before each use. Samples should be taken from the center of the mass of soil retrieved by the sampler, avoiding material that has come in contact with the walls of the sampler. Liner materials or tubes for tube samplers may be selected to avoid sample contamination. For example, plastic liners or tape used to seal containers may be a source of contamination for organic compounds.
- Adequate field control samples should be collected.

C.6.4 Sampling methods. Presented in the following sections are sampling instructions for the most common techniques of collecting soil samples. Prior to sample collection, the soil sampling location and characteristics (soil type, depth) should be recorded in the field logbook. Selection of soil sampling equipment is usually based on the depth of the samples. Manual techniques are usually selected for surface or shallow subsurface soil sampling. At greater depths, mechanically driven equipment is usually required to overcome torque induced by soil resistance and depth. Additional information on collecting soil samples is presented in EPA/540/4-91/001, EPA/625/R-93/003A, ASTM D 4700, ASTM D 6169, and D 5730. ASTM Standards for specific applications of waste management include D 4547 and C 998.

C.6.4.1 Spade and scoop. Method Reference: ASTM D 5633.

C.6.4.1.1 Applicability. The spade and scoop method is a very accurate, representative method for collecting surface and shallow subsurface soil samples. This method is usually limited to soil depths less than 30 cm (1 ft).

C.6.4.1.2 Method summary and equipment. The simplest, most direct method of collecting surface soil samples is to use a spade and stainless steel scoop (Figure C-10 in Instruction C-5). A typical garden spade can be used to remove the top cover of soil to the required depth, but the smaller stainless steel scoop should be used to collect the sample. When a garden spade is used, the spade should be decontaminated before use; and if the spade is driven into the soil with the sampler's field boot, the boot should be covered with a clean disposable overboot. Typical garden-type scoops are many times plated with chrome or other metals and would, therefore, be inappropriate for sampling when analyzing for metals.

C.6.4.1.3 Sampling procedure. The guidance provided for use in shallow sediment collection, Section C.5.4.1.3, is appropriate for surficial soils collection with a spade or scoop.

C.6.4.2 Hand auger and tube sampler. Method Reference: ASTM D 1452 and D 4700.

C.6.4.2.1 Applicability. Equipment for the hand auger is portable and easy to use. Discrete subsurface soil samples can be collected efficiently without the use of a drill rig. Disadvantages of the hand auger include its limited sampling depth. The tube sampler may not penetrate gravelly or rocky soils.

C.6.4.2.2 Method summary and equipment. Hand augers are the simplest and most direct method for sampling subsurface soil samples (Figure C-11 and Figure C-12). Although the maximum sampling depth for the hand auger is typically 1.5 m (5 ft), greater depths can be sampled depending on the soil type. Hand augers come in various diameters and various types. The auger bit is used to bore a hole to the desired sampling depth and then withdrawn. The auger tip is then replaced with the tube corer, lowered into the borehole, and forced into the soil at the completion depth. The corer is then withdrawn and the sample is collected.

C.6.4.2.3 Sampling procedure. The guidance provided for use in sediment collection, Section C.5.4.3.3, is appropriate for soils collection with a hand auger and tube sampler.

C.6.4.3 Split-spoon sampler. Method Reference: ASTM D 1586.

C.6.4.3.1 Applicability. The split-spoon sampler is used for sampling subsurface soil in cohesive- and noncohesive-type soils. It is used extensively for collecting subsurface soil samples for chemical analysis. The split-spoon sampler will require a drill rig and crew for collecting samples greater than 1.5 m (5 ft).

C.6.4.3.2 Method summary and equipment. The split-spoon sampler is typically a 5- to 11.5-cm- (2- to 4-1/2-in.-) diam., thick-walled, steel tube that is split lengthwise (Figure C-13). If a 5-cm- (2-in.-) diam. split-spoon sampler is used, then standard penetration tests can be taken to determine the density of the soil. A cutting shoe is attached to the lower end; the upper end contains a check valve and is connected to the drill rods. When a boring is advanced to the point that a sample is to be taken, drill tools are removed and the sampler is lowered into the hole on the bottom of the drill rods. The sampler is driven into the ground in accordance with the standard penetration test (Appendix B of EM 1110-1-1906). Recently, the U.S. Army Engineer District, Mobile, has remanufactured the connection between the split-spoon sampler

and the drill rods headpiece from threads to a quick connect/release mechanism. The sampler is referred to as the Sanford quick-connect split- spoon sampler, named after its designer, Johnny Sanford. The Sanford split-spoon sampler (Figure C-17) is manufactured with one-half of the split spoon permanently attached to the sampler head, the other half sliding up into the head, and the driving shoe threaded onto both halves completing the assembly. By eliminating the need to screw and unscrew the upper end of the split tube, there is less disturbance to the soil core and a significant amount of time is saved.

C.6.4.3.3 Sampling procedure. The sampling procedure is as follows:

- Place plastic sheeting on the ground around the sampling location to prevent cross-contamination.
- Assemble the sampler by aligning both sides of the barrel and then screwing the drive shoe on the bottom and the sampler head on top. The Sanford quick-connect split-spoon sampler is assembled as noted in the preceding section.
- Place the sampler in a perpendicular position on the material to be sampled.
- Drive the tube, using a sledge hammer or drill rig if available. Do not drive past the bottom of the headpiece because this will result in compression of the sample.
- Record the length of the tube that penetrated the material being sampled and the number of blows required to obtain this depth. Typically, the number of blows per 15 cm (6 in.) of depth is recorded.
- Withdraw the sampler, disconnect from the drill rods (if necessary), and open it by unscrewing the drive shoe and head and splitting the barrel. Record appropriate information for soil core logging per EM 1110-1-4000 (i.e., soil depth, type, and classification).
- Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as possible to the media. If split samples are desired, a decontaminated stainless steel knife should be used to split the tube contents in half longitudinally. Refer to Instruction E-4 for additional information on the collection, handling, and storage of solid VOA samples.
- If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing. Refer to Instructions E-2 and E-3, Appendix E, respectively, for procedures to follow for these techniques.
- Transfer sample into an appropriate sample bottle with a stainless steel laboratory spoon or equivalent.
- Secure the cap tightly.
- Label the sample bottle with the appropriate sample label. Be sure to label the bottle carefully and clearly, addressing all the categories or parameters.
- Place filled sample containers on ice immediately.

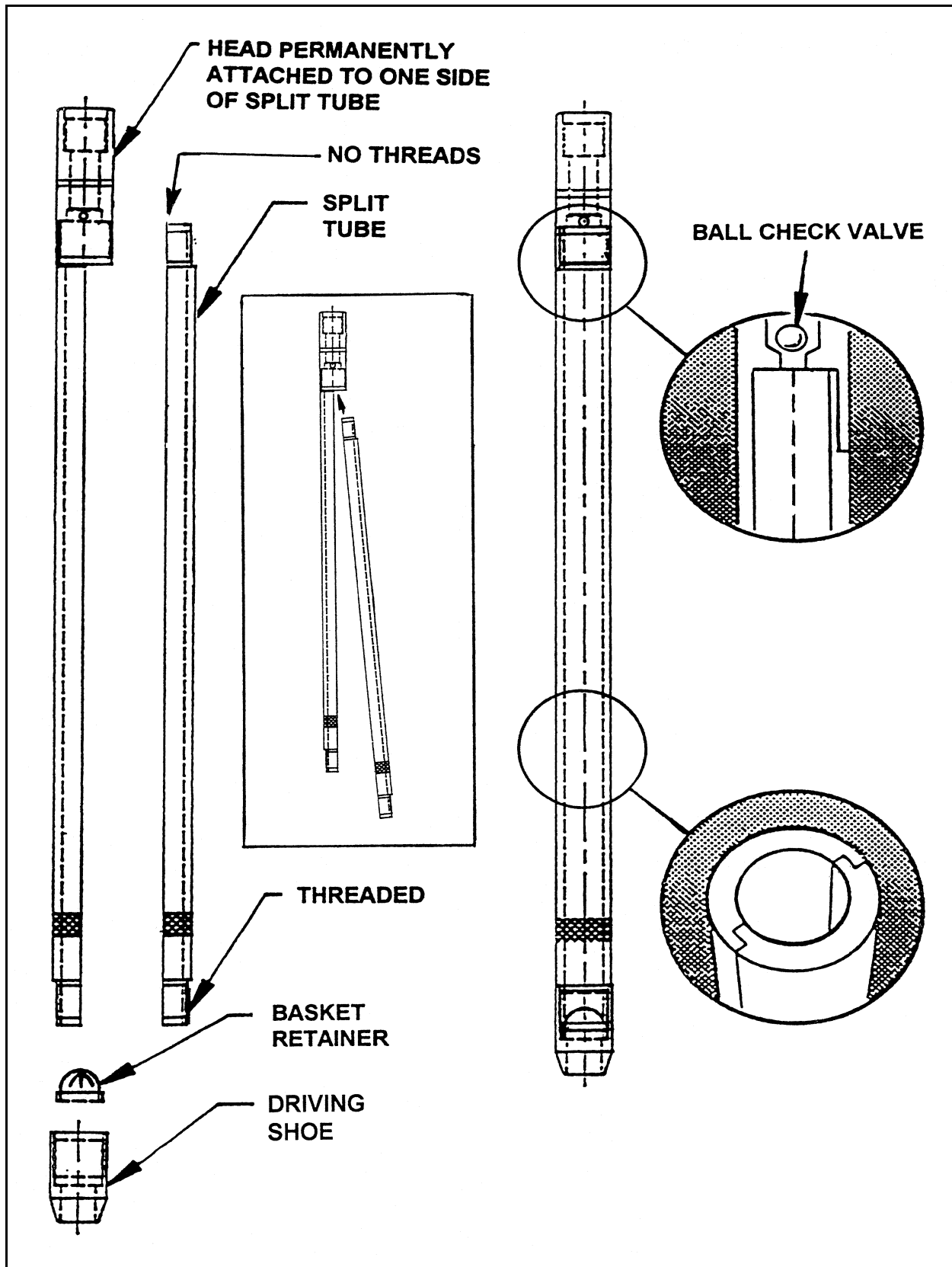


Figure C-17. Sanford quick-connect split-spoon sampler

- Complete all chain-of-custody documents and record information in field logbook (see Instruction F-1, “Documentation,” Appendix F). Prepare samples for shipment (see Instruction F-2, “Packaging and Shipping Procedures,” Appendix F).
- Decontaminate sampling equipment after use and between sampling locations.

C.6.4.4 Ring-lined barrel sampler. Method Reference: ASTM D 3550.

C.6.4.4.1 Applicability. The ring-lined barrel sampler provides the ability to collect samples without losing volatiles or moisture. Soil is contained in the rings, and the sampler can be easily and quickly capped after it is removed. The relatively small size of the rings allows easy sample shipping and handling. However, the opportunity for describing the soil is diminished because most of the soil is concealed in the ring apparatus. Since rings are not always accepted by the laboratory, prior arrangements should be made with the laboratory.

C.6.4.4.2 Method summary and equipment. Ring-lined barrel samplers are typically 7.5 cm (3 in.) in diameter and are used to obtain representative subsurface soil samples with a split sampling barrel that has removable rings. The rings are typically constructed of plastic, stainless steel, or brass and fit inside the barrel assembly. Rings are commonly used within the California Modified sampler and are typically 7.5 cm (3 in.) long.

C.6.4.4.3 Sampling procedure. The sampling procedure is as follows:

- Place plastic sheeting on the ground around the sampling location to prevent cross-contamination.
- Assemble the sampler by placing eight 7.5-cm- (3-in.-) long rings in the 60-cm- (2-ft-) long sampler. Align both sides of the barrel and screw the drive shoe on the bottom and the heavier headpiece on top.
- Place the sampler in a perpendicular position on the material to be sampled.
- Drive the tube, using a sledge hammer or drill rig if available. Do not drive past the bottom of the headpiece because this will result in compression of the sample.
- Record the length of the tube that penetrated the material being sampled and the number of blows during each 15-cm (6-in.) increment.
- Withdraw the sampler and open it by unscrewing the drive shoe and head and the splitting barrel. Remove the sampling rings. Trim the soil at the end of the rings so that it is flush with the endings. For chemical samples, cap the end of the rings with a PTFE-lined plastic cap. For geotechnical samples, a plastic cap is suitable.
- Label the sample ring with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- Place sealed sample rings on ice immediately.
- Complete all chain-of-custody documents and record information in the field logbook (see Instruction F-1, “Documentation,” Appendix F). Prepare samples for shipment (see Instruction F-2, “Packaging and Shipping Procedures,” Appendix F).

- Decontaminate sampling equipment after use and between sampling locations.

C.6.4.5 Thin-walled (Shelby) tube sampler. Method Reference: ASTM D 1587.

C.6.4.5.1 Applicability. Thin-walled tube samplers allow collection of undisturbed samples in cohesive-type soils (i.e., clays). They are used primarily for collecting soil samples for certain geotechnical tests. Thin-walled tube samplers are not the ideal containers for transporting samples to the laboratory for chemical analysis due to their size. The opportunity for describing the soil is diminished because most of the soil is concealed in the tube.

C.6.4.5.2 Method summary and equipment. The thin-walled tube sampler is designed to take undisturbed samples in cohesive-type soils (Figure C-18). The thin-walled tube sampler is available in either brass, galvanized steel, plain steel, or stainless steel and is manufactured in either 76- or 91-cm (30- or 36-in.) lengths. These tubes normally have an outside diameter of 7.5 to 12.5 cm (3 to 5 in.); however, the 7.5-cm (3-in.) diameter is the most commonly used. Thin-walled tube samplers are usually used for sampling cohesive soils for geotechnical evaluation, rather than chemical analysis.

C.6.4.5.3 Sampling procedure. The sampling procedure is as follows:

- C Place plastic sheeting on the ground around the sampling location to prevent cross-contamination.
- C Place the sampler in a perpendicular position on the material to be sampled.
- C Push the tube into the soil by a continuous and rapid motion, without impact or twisting. In no instance should the tube be pushed further than the length provided for the soil sample.
- C When the soil is so hard that a pushing motion will not penetrate the sample sufficiently for recovery, it may be necessary to collect a disturbed sample with the split-spoon sampler. Extremely dense and hard soils may result in damage to the thin-walled tube sampler.
- C Before pulling out the tube, rotate the tube at least two revolutions to shear off the sample at the bottom. For geotechnical analysis, seal the ends of the tube with wax or rubber packers to preserve the moisture content. In such instances, the procedures and preparation for shipment

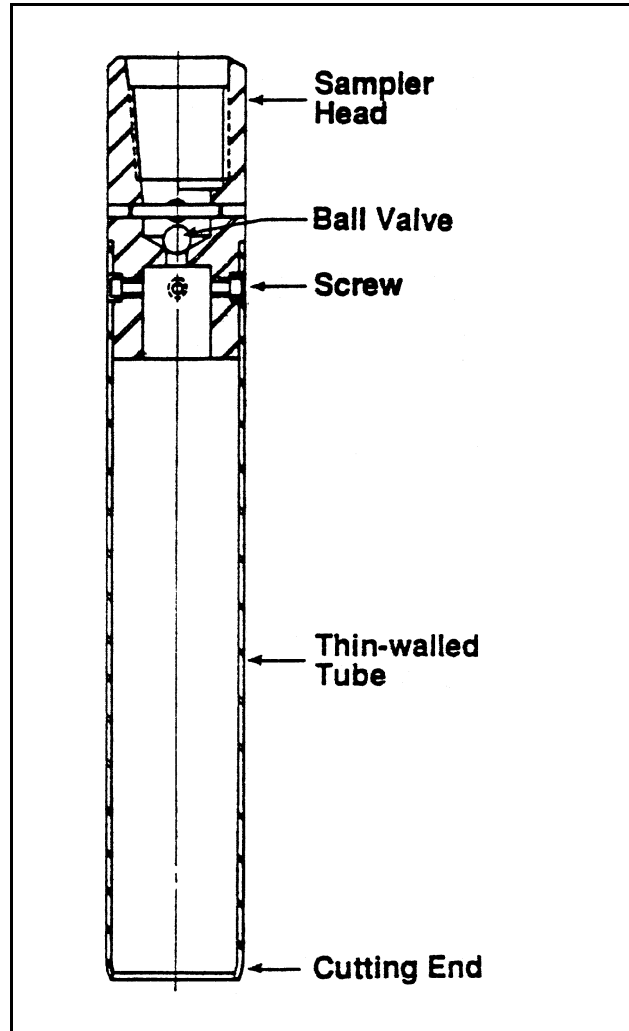


Figure C-18. Standard thin-walled (Shelby) tube sampler

should be in accordance with ASTM D 1587. For chemical samples, seal the ends of the tube with PTFE-lined plastic caps.

- C Label the sample tube with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Complete all chain-of-custody documents and record information in the field logbook (see Instruction F-1, "Documentation," Appendix F). Prepare samples for shipment (see Instruction F-2, "Packaging and Shipping Procedures," Appendix F).
- C Decontaminate sampling equipment after use and between sampling locations.

C.6.4.6 Continuous tube sampler. Method Reference: ASTM D 4700.

C.6.4.6.1 Applicability. The continuous tube sampler provides good samples for describing soil profiles because of the long length of the samples. Discrete samples for chemical analysis can be collected only within a 1.5-m (5-ft) increment. This sampler may not be effective in noncohesive soil types and requires the use of a drilling rig.

C.6.4.6.2 Method summary and equipment. The continuous tube sampler fits within a hollow-stem auger and is prevented from rotating as the auger is turned. The sampling tube can be split or solid barrel and can be used with or without liners of various metallic and nonmetallic materials. The sampler is illustrated in Figure C-19, and is typically 1.5 m (5 ft) long and 5 to 15 cm (2 to 6 in.) in diameter.

C.6.4.6.3 Sampling procedure. The sampling procedure is as follows:

- C Place plastic sheeting on the ground around the sampling location to prevent cross-contamination.
- C Lock the sampler in place inside the hollow-stem auger with its open end protruding a short distance beyond the end of the auger.
- C Advance the auger while soil enters the nonrotating sampling tube.
- C After advancing the length of the sampling tube, withdraw the sampler and remove the liner (if used) and cap. If a split-tube sampler is used, and chemical samples are desired, use a decontaminated stainless steel knife to divide the split-tube contents in half longitudinally.
- Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as possible to the media. Refer to Instruction E-4 for additional information on the collection, handling, and storage of solid VOA samples.
- C If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing.
- Thoroughly mix remaining sample as outlined in Instructions E-2 or E-3 as appropriate and collect the sample into an appropriate sample bottle with a stainless steel laboratory spoon or equivalent.

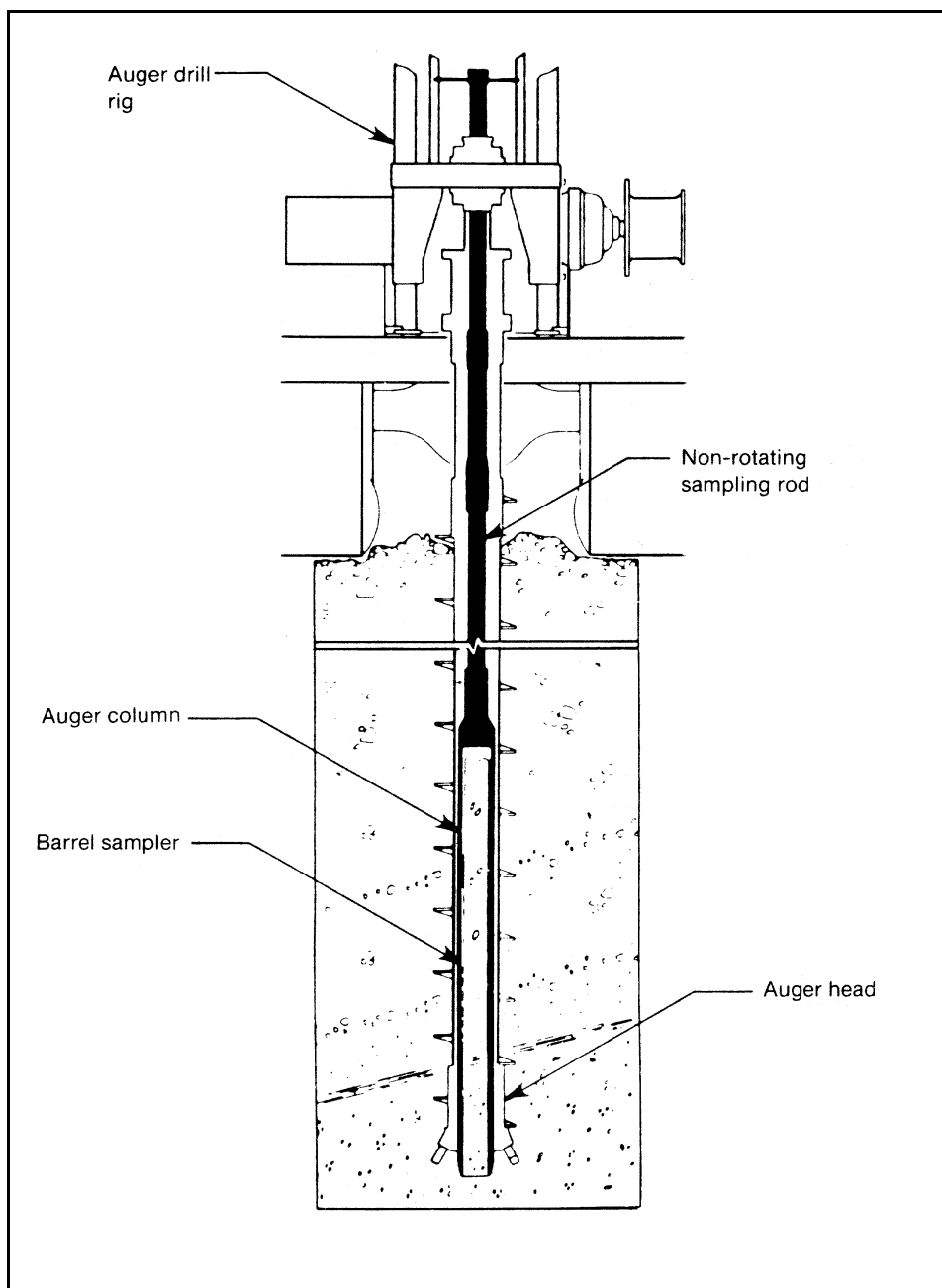


Figure C-19. Continuous tube sampler

- C Secure the cap tightly.
- C Place filled sample containers on ice immediately.
- C Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.

- C Complete all chain-of-custody documents and record information in the field logbook (see Instruction F-1, "Documentation," Appendix F). Prepare samples for shipment (see Instruction F-2, "Packaging and Shipping Procedures," Appendix F).
- C Decontaminate sampling equipment after use and between sampling locations.

C.6.4.7 Piston sampler. Method Reference: ASTM D 4700.

C.6.4.7.1 Applicability. Piston samplers are used to collect soft subsurface soils that cannot be collected using other techniques.

C.6.4.7.2 Method summary and equipment. The piston sampler (Figure C-20) consists of a sampling barrel with a piston that is retracted during sampling. Retraction of the piston creates a vacuum within the sample barrel that aids in retaining the sample in the barrel. Various piston type samplers are available, and each should be operated per the manufacturer's recommendations. EM 1110-1-1906 and EPA/625/R-93/00a discuss the use of a piston sampler.

C.6.4.7.3 Sampling procedure. The sampling procedure is as follows:

- C Assemble decontaminated piston sampler and attach to rods that will lower the sampler down the borehole.
- C Lower sampler to the desired depth. Advance the sampler into the soil while actuating the piston to create a vacuum within the sample barrel.
- C Carefully remove the piston sampler from the bore hole.
- C Begin sampling with the acquisition of any grab VOC samples, conducting the sampling with as little disturbance as possible to the media. Refer to Instruction E-4 for additional information on the collection, handling, and storage of solid VOA samples.
- C If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing

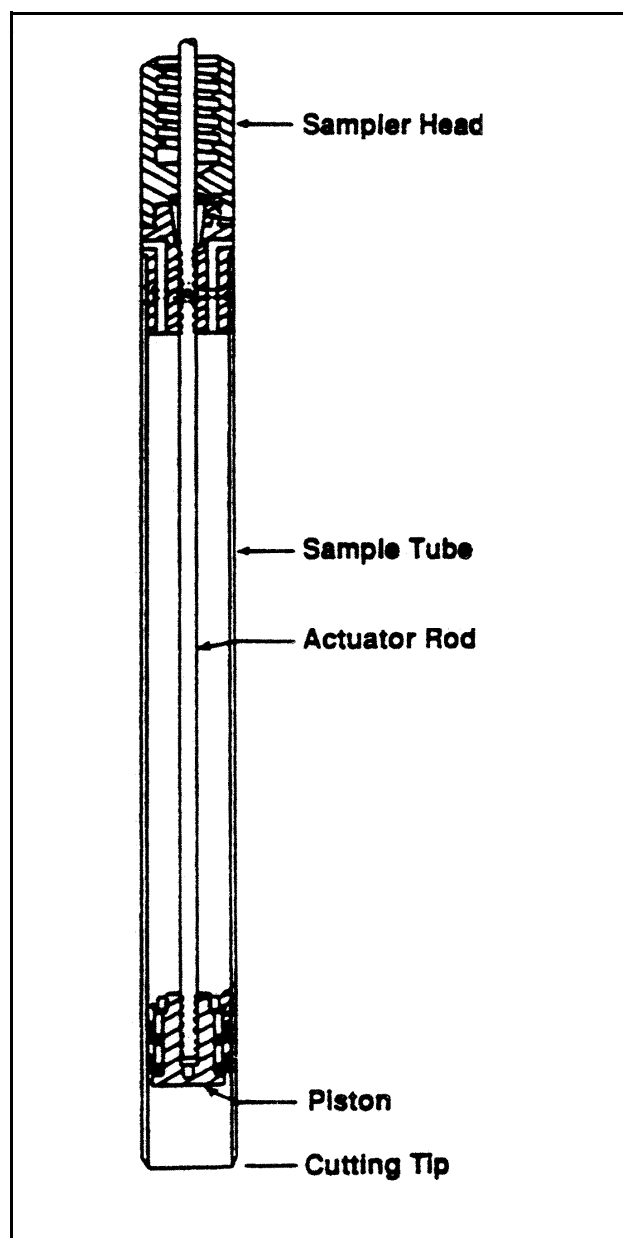


Figure C-20. Piston sampler (after ASTM D 4700, reprinted, with permission, from the Annual Book of ASTM Standards, copyright American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959)

of different locations is desired, transfer the sample to a stainless steel bowl for mixing. Refer to Instructions E-2 and E-3, Appendix E, respectively, for procedures on these techniques.

- Collect the sample into an appropriate sample bottle with a stainless steel laboratory spoon or equivalent.
- C Label the sample bottle with the appropriate sample label. Complete the label carefully and clearly, addressing all the categories or parameters.
- C Place the sample in an appropriate container and put the container on ice.
- C Complete all chain-of-custody documents and field sheets and record in the field logbook (see Instruction F-1, "Documentation," Appendix F). Prepare samples for shipment (see Instruction F-2, "Packaging and Shipping Procedures," Appendix F).
- C Thoroughly decontaminate the sampler after each use.

C.6.4.8 Core barrel. Method Reference: ASTM D 2113.

C.6.4.8.1 Applicability. Core barrel or rotating core samplers advance by cutting away rock or soil material using a circular cutting bit as the shoe of the stationary inner core barrel advances into the rock or soil. Core barrel sampling is used primarily for collecting samples for rock profiling purposes. Rock samples are not typically submitted for chemical analysis.

C.6.4.8.2 Method summary and equipment. Core barrel drilling is used to obtain samples of rock or soils that are too hard to sample by soil sampling methods. Double-tube core barrels work the best. Core bits used for this type of sampling are typically impregnated with diamonds or carbide slugs that cut through the formation allowing a continuous sample to be collected.

C.6.4.8.3 Sampling procedure. The sampling procedure is as follows:

- C Place the core barrel into position with the bit touching the ground or the surface to be cored.
- C Continue core drilling until core blockage occurs or until the net length of the core barrel has been drilled.
- C Remove the core barrel from the hole and disassemble it as necessary to remove the core.
- C Refer to ASTM D 5079 "Preserving and Transporting Rock Core Samples" and EM 1110-1-1906 for sample handling procedures.
- C Place the recovered core in a core box with the upper end of the core at the upper left corner of the core box. Cores should be placed in the core box as a book would read, from left to right and top to bottom, within the longitudinal separators. Space blocks or plugs should be securely placed at the beginning of each core run. The space blocks should be plainly marked with the depth of the core run. Spacers should also be securely placed in the proper positions in the core boxes and properly marked to show the location and actual extent of any voids and/or core losses during drilling.

- C When a hole is completed, a space block marked “Bottom of Hole,” or “BOH” should be securely placed after the last core run. Appropriately marked space blocks should also be inserted in the core boxes to fill the spaces formerly occupied by core that has been removed for testing.
- C Core boxes should be marked on the outside to indicate the top and bottom, and the inside upper left corner of the box should be permanently marked with the letters UL to indicate the upper left corner.
- C Soft or friable cores should be wrapped in plastic film or sealed in wax.
- C When samples are collected with a core barrel and placed into a core box, the core samples should be photographed in the core box as soon as possible after the core samples are retrieved and the box is labeled.
- C The core box lid should be marked both inside and outside with the project name, hole number, location, surface elevation, box number, and depths for the beginning and end of core in the box. The ends of the core box should be marked with the project name, hole number and box number.

C.6.4.9 Direct Push Soil Sampling. Method Reference: ASTM D 6282.

C.6.4.9.1 Applicability. The direct push soil sampling method is widely used as a preliminary site characterization tool for the initial field activity of a site investigation. Direct push sampling is an economical and efficient method for obtaining discrete soil and water samples without the expense of drilling and its related waste cuttings disposal costs.

C.6.4.9.2 Method summary and equipment. The sampling method, known as the direct push method, involves sampling devices that are directly inserted into the soil to be sampled without drilling or borehole excavation. Direct push sampling consists of advancing a sampling device into the subsurface by applying static pressure, impacts, or vibration or any combination thereof to the aboveground portion of the sampler extensions until the sampler has been advanced its full length into the desired soil strata. No specific guidance or standards document the “direct push sampling method,” but the guidance is a modification of standards from the Shelby tube, split spoon, piston, and penetrometer methods. The method is employed under various protocols by commercial entities and called by various proprietary names (i.e., Geoprobe). Direct push methods may be used to collect soil, and in some cases, the method may be combined with sampling devices capable of water and/or vapor sampling. The equipment generally used in direct push sampling is small and relatively compact allowing for better mobility around the site and access to confined areas. Direct push insertion methods include static push, impact, percussion, other vibratory driving, and combinations of these methods using direct push equipment adapted to drilling rigs, cone penetrometer units (the reference standard for which is ASTM D 5778-95, and specially designed percussion/direct push combination machines. Standard drilling rods used for rotary drilling are sometimes used when sampling is done at the base of drill holes. A direct push soil sampling system consists of a sample collection tool; hollow extension rods for advancement, retrieval, and transmission of energy to the sampler; and an energy source to force penetration by the sampler.

C.6.4.9.3 Sampling procedure. The sampling procedure is as follows:

- C Assemble decontaminated direct push sampling device that will be pushed into the ground to collect data or samples.

- C Advance the sampling device into subsurface soils by applying static pressure, impacts, or vibration or any combination thereof to the aboveground portion of the sampler extensions until the sampler has been advanced its full length into the desired soil strata.
- C Sampling can be continuous for full-depth borehole logging or incremental for specific strata sampling. Samplers used can be protected for controlled specimen gathering or unprotected for general data collection.
- C Recover the sampler from the borehole and remove the soil sample from the sampler.
- C Begin sampling with the acquisition of any VOC samples, conducting the sampling with as little disturbance as possible to the media. Refer to Instruction E-4 for additional information on the collection, handling, and storage of solid VOA samples.
- C If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of a different location is desired, transfer the sample to a stainless steel bowl for mixing. Refer to Instructions E-2 and E-3, Appendix E, respectively.
- C Transfer sample into an appropriate sample bottle using a stainless steel spoon or equivalent.
- C Check that a PTFE liner is present in the cap. Secure the cap tightly.
- C Label the sample bottle. Complete the label completely and clearly, addressing all the categories and parameters.
- C Place filled sample containers on ice immediately.
- C Complete chain-of-custody documents and field sheets and record in the logbook (see Instruction F-1, "Documentation," Appendix F).
- C Prepare samples for shipment (see Instruction F-2, "Packaging and Shipping Procedures," Appendix F).
- C Decontaminate the equipment following each probe or sample.

C.6.4.10 Site Characterization and Analysis Penetrometer System (SCAPS).

C.6.4.10.1 Applicability. The SCAPS system provides the capability to conduct rapid site characterization and real-time analysis of contaminated soil and ground water in situ. SCAPS may be used to determine areas free of contamination, optimize the selection of monitoring well locations, and provide onsite three-dimensional visualization of soil stratigraphy and contaminant plumes. SCAPS site characterization may save from 25 to 30 percent of site characterization costs compared with those of conventional drill and sampling techniques. SCAPS sensors have the capability for determining soil classification/layering and detecting contaminants simultaneously. Geotechnical and contaminant sensing technologies currently available include soil classification; electrical resistivity; POL; explosives; VOCs; and gamma-emitting radionuclides. Regulatory certification has been granted for the SCAPS POL and is ongoing for VOCs, explosives, and metals sensors under the Environmental Security Technology Certification Program (ESTCP) and by the USEPA Consortium for Site Characterization Technologies, the California EPA Environmental Technology Certification Program, and reciprocity via the Interstate Technology Regulatory Cooperation

(ITRC) Workgroup. SCAPS technology has been transitioned to USACE, Department of Defense, Department of Energy, USEPA, and other government agency users and to the private sector through licensing and Cooperative Research and Development Agreements (CRADA).

C.6.4.10.2 Method summaries and equipment. The SCAPS platform consists of a 20-ton truck (Figure C-21) equipped with vertical hydraulic rams that are used to force a cone penetrometer into the ground at a speed of 2 cm/sec to depths of approximately 50 m in nominally consolidated fine-grained soils. During a vertical push, data are continuously collected and recorded with 2-cm depth resolution. The truck consists of two separate enclosed compartments (i.e., the data acquisition/processing room and the hydraulic ram/rod handling room). SCAPS multisensor penetrometer probes are equipped to measure tip and sleeve resistances simultaneously to determine soil stratigraphy, layer boundaries, and soil type as well as contaminant-specific sensor data to determine the presence of pollutants in each soil strata. SCAPS data acquisition consists of real-time data acquisition, electronic signal processing equipment, and a postprocessing computer for three-dimensional visualization of stratigraphy and contaminant plumes. The soil sampler used with the cone penetrometer consists of a lined steel cylinder with a retractable tip. The liner (typically a plastic type material) is placed in the sampler and the retractable tip is set at the bottom end of the sampler. The sampler is then advanced to the top of the interval where the soil sample is to be collected. The tip is remotely released and the sampler is pushed ahead into the interval to be sampled. Using this procedure, the soil sampler is pushed to the desired depth and the sample is collected without producing soil cuttings typically generated during soil boring activities. This type of soil sampler can be used with equipment other than cone penetrometers. A mobile laboratory truck may accompany the SCAPS to augment field analytical capabilities with the addition of an ion trap mass spectrometry and/or gas chromatography to analyze vapor samples collected by SCAPS samplers. In addition, the SCAPS can inject grout into the borehole through the probes as they are being withdrawn from the ground. This maintains isolation of contaminants in the subsurface.

C.6.4.10.3 Sampling procedures. The sampling procedures are as follows:

- C Assemble decontaminated cone penetrometer device that will be pushed into the ground to collect data or samples.
- C Push the data collection tip to the desired depth and record the data on the onboard computer. For the soil sampler, advance the sampler to the top of the interval to be sampled, release the tip, and advance the sampler to collect the soil sample.
- C Following removal of the soil sample, backfill the hole by pumping grout through the tip as it is retracted, using the tremie method, or by pouring the grout into the hole from the ground surface.
- C Remove the liner from the soil sampler and begin sampling with the acquisition of any VOC samples, conducting the sampling with as little disturbance as possible to the media. Refer to Instruction E-4 for additional information on the collection, handling, and storage of solid VOA samples.
- C If homogenization of the sample location is appropriate for the remaining analytical parameters or if compositing of a different location is desired, transfer the sample to a stainless steel bowl for mixing. Refer to Instructions E-2 and E-3, Appendix E, respectively, for procedures to follow for these techniques.
- C Transfer sample into an appropriate sample bottle using a stainless steel spoon or equivalent.

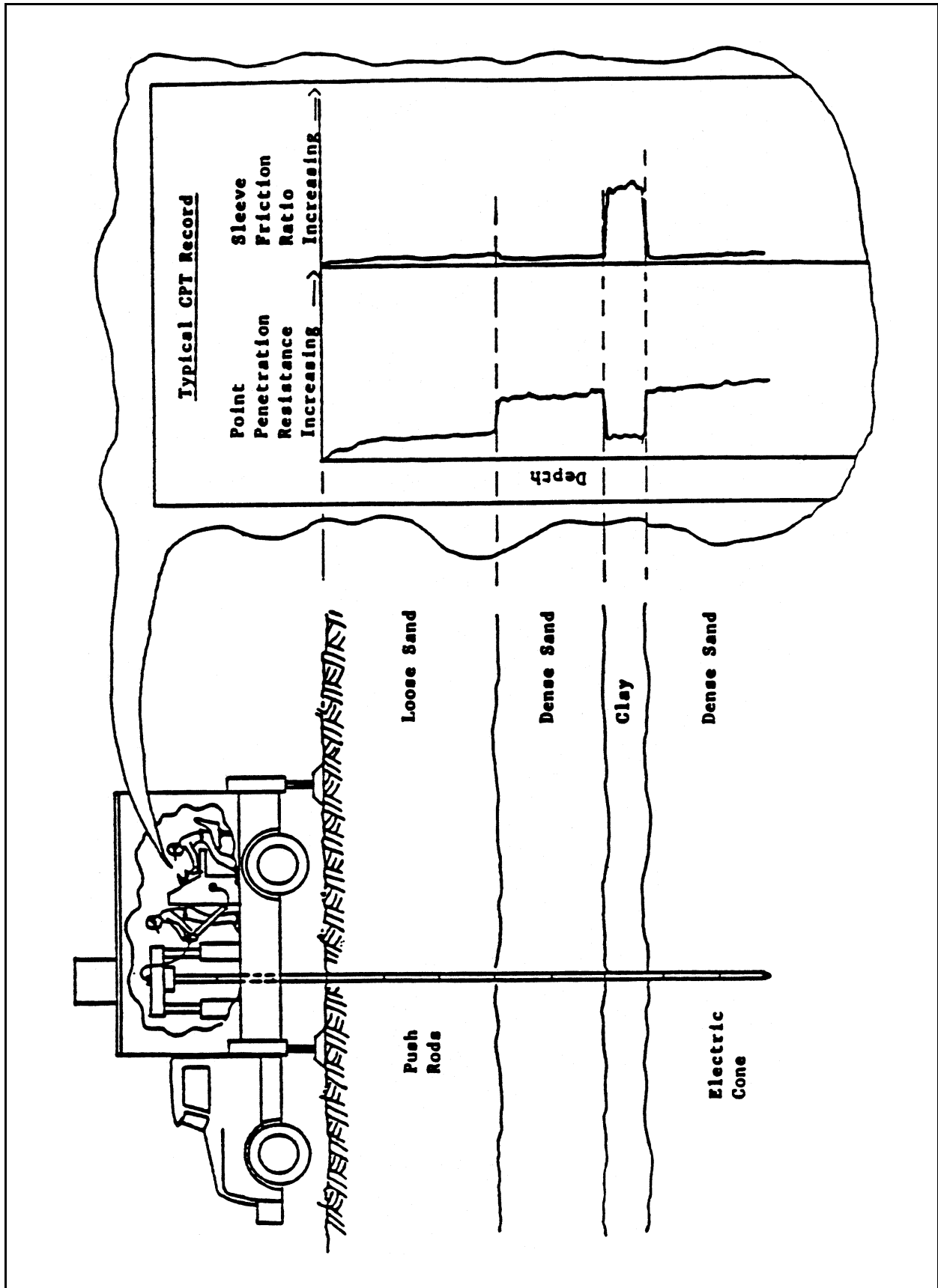


Figure C-21. Site characterization and analysis penetrometer system (SCAPS) truck schematic (CPT = cone penetrometer testing)

- C Check that a PTFE liner is present in the cap. Secure the cap tightly.
- C Label the sample bottle. Complete the label completely and clearly, addressing all the categories and parameters.
- C Place filled sample containers on ice immediately.
- C Complete chain-of-custody documents and field sheets and record in the logbook (see Instruction F-1, "Documentation," Appendix F).
- C Prepare samples for shipment (see Instruction F-2, "Packaging and Shipping Procedures," Appendix F).
- C Decontaminate the equipment following each probe or sample.

C.6.4.10.4 Field analysis capabilities. The SCAPS has the following capabilities:

- C Thermal Desorption VOC Sampler: detects and maps solvent and hydrocarbon contamination in both the vadose and saturated zones. Extracts vapor from in situ soil at penetrometer tip and retrieves vapor samples to surface for analysis.
- C Hydrosparge VOC Sensing System: samples ground water by direct push tool, strips VOC from ground water by helium flow ("sparging"), and retrieves VOCs for analysis in ion trap mass spectrometer or other device.
- C Explosives Sensor: incorporates electrochemical sensors inside the tip for analyzing unexploded ordnance in the contaminated strata; incorporates geophysical sensors for soil classification simultaneous with chemical analyses output at surface.
- C Multiport Sampler (MPS): contains vertically stacked sampling modules independently operated from the surface for collecting multiple vapor samples in a single penetration without cross-contamination; alternative immediate retrieval of collected samples or retention for later retraction of probe.
- C Laser Induced Fluorescence (LIF) Petroleum, Oil, and Lubricant (POL) Sensor: uses ultraviolet laser to induce fluorescence in POL contaminants in situ; returned fluorescent energy processed for spectral analysis of components in POL.
- C Laser Induced Breakdown Spectroscopy (LIBS): a high-power focused laser creates a plasma (dissociates molecules and atoms in soil and energizes them) that emits electromagnetic radiation, which can then be analyzed by spectrometer for atomic content.
- C X-Ray Fluorescence (XRF) Metals Sensor: uses x-ray excitation to fluoresce metal atoms independent of chemical states; characteristic energy emissions identify specific metals to well below 100 ppm concentrations.
- C Enhanced Spectral Gamma Sensor: detects gamma radiation from radio nuclides for identification by gamma ray spectroscopy.

C.6.5 Decontamination procedures. All sampling equipment must be decontaminated prior to its use. Sampling equipment should be decontaminated as described in Instruction E-5 (Appendix E). The sampling equipment should be placed in plastic bags until immediately prior to use. Additional sampling devices may be needed onsite to ensure an adequate drying time.

C.6.6 Field control sample requirements. Field control samples are collected by the sampling team to determine whether the data are of suitable quality. They include blanks, replicates, and/or background samples. QA samples are replicates sent to a referee (QA) laboratory and analyzed to evaluate the contractor's laboratory performance. QC samples are blind replicates collected by the sampling team for analysis by the primary laboratory. A detailed discussion of field control samples is contained in Instruction G-2 (Appendix G).

C.6.7 Documentation requirements. Bound field logbooks should be used for the maintenance of field records. Record all aspects of the site set up, sample collection and handling as outlined above and in Instruction F-1, Appendix F.

C.7 Surficial Sampling

C.7.1 Scope and application. This instruction presents guidelines for collecting representative samples from various surfaces. Surficial sampling is used to assess the existence and/or extent of contamination on various surfaces rather than in a soil, water, or air matrix. For example, the contamination of the interior of a building may be assessed by collecting wipe samples of the process vessels and ventilation ducts. Surface samples are not typically analyzed for VOCs. Typical sample parameters include PCBs, dioxans/furans, pesticides, semivolatiles, metals, and explosives. Surface samples are typically divided into three media: nonporous surfaces, porous surfaces, and dust/soot. Nonporous surfaces can be sampled by wipe sampling; porous surfaces can be sampled by chipping or coring the surface; and dust/soot can be sampled by vacuum or sweep sampling. Instructions for these techniques are included in this section. If these methods are difficult to implement due to irregular surface shapes or other limitations, a rinsate sample can be collected.

C.7.2 Sampling strategies. The data from surficial sampling are typically required for risk assessments or compliance issues. Therefore, the sampling strategy is based either on a biased approach to locate and/or identify contamination or a systematic approach for decontamination verification.

C.7.2.1 Sampling locations. Sampling at hazardous waste sites is usually conducted in an attempt to discover contamination and to define its extent and variability. With such an objective, it is most logical to choose sample locations that will yield the most information about site conditions. Surficial sampling can be conducted by either biased or systematic sampling. Biased samples are those collected at locations that were chosen based on historical information, knowledge about the behavior of the contaminant(s), and/or knowledge about the effects of the physical system on the fate of the contaminant. Specific requirements for selecting sampling locations may be applicable for risk assessments or verification of cleanup levels. For example, sampling locations for verification of PCB cleanup levels are established in 40 CFR 761. Additional guidance for selecting sampling locations can be found in EPA/600/2-85/028, EPA/560/5-85/026, and EPA/560/5-86/017.

C.7.2.2 Types of samples. Surficial samples are discrete samples. Discrete (grab) samples are defined as a discrete aliquot representative of a specific location at a given point in time. The sample is collected immediately and at one particular point in the sample matrix. Representativeness of such samples is defined by the nature of the materials being sampled.

C.7.2.3 Suggested samplers. Each sampling technique presents various disadvantages and advantages for its application. For example, sample disturbance, sample volume, compatibility with planned chemical analysis, and chemical/physical reactivity between potential contaminants and sampling tool materials vary from technique to technique. Discussions of the advantages and disadvantages of each sampling technique are presented in the following sections.

C.7.2.4 Sample frequency. Determination of the number of samples needed to characterize a site also depends on the objectives and the site-specific conditions. For example, if the objective of the event is to determine whether site equipment is contaminated, a limited number of samples from properly chosen locations will yield useful information. If, however, the site structures are known to be contaminated and delineation of the contamination is the objective, a greater number of samples may be needed. Confirmatory sampling for the effectiveness of the decontamination procedure may warrant specific sample frequency requirements. In many cases statistical considerations can be helpful in determining sampling strategy.

C.7.3 Sample preservation and handling. Many of the chemical constituents and physicochemical parameters that are to be measured or evaluated in investigation programs are not chemically stable; therefore, sample preservation is required. Chip, core, sweep, and vacuum samples should be handled in the

same fashion as sediment/soil samples. Wipe samples do not designate a specific preservation technique, but the use of amber glass may provide protection from light, and/or cooling may be employed as precautionary measures. Appropriate preservation techniques for various parameters are specified in Appendix B. In addition, sample containers that the sampler should use for each constituent or common set of parameters are specified in Appendix B. These preservation methods and sample containers are based on EPA/SW-846. Procedures and techniques for transporting the samples to the offsite laboratory are discussed in Instruction F-2, "Packaging and Shipping Procedures," Appendix F.

C.7.3.1 Sample containers. Chip, core, and sweep samples should be placed in sample jars as designated for soil samples by the chemical parameters of interest. Wipe samples should be placed in amber jars. The cleanliness of each lot of precleaned bottles should be verified by the container supplier or in the laboratory and appropriate paperwork (i.e., certificates) retained with other field documentation. Vacuum samples involve the acquisition of dust onto an air monitoring filter cassette, which includes the appropriate pore size (i.e., 0.8 micron) polycellulose acetate filter. Post sampling, end plugs are secured on the filter cassette for shipment to the laboratory.

C.7.3.2 Sample preservation. Methods of sample preservation are relatively limited and are generally intended to retard biological action and hydrolysis and to reduce sorption effects. Preservation methods are generally limited to refrigeration and protection from light. The sampler should refer to Appendix B or the specific preservation method in EPA/SW-846 for the appropriate preservation technique.

C.7.3.3 Special precautions for trace contaminant sampling. Contaminants can be detected in the parts per billion and/or parts per trillion range. Therefore, all equipment must be thoroughly inspected for cleanliness prior to use and extreme care be taken to prevent cross-contamination of these samples. The following general precautions should be taken when sampling:

- A clean pair of new, disposable gloves and shoe covers, if necessary, should be worn each time a different location is sampled. Gloves should be donned immediately prior to sampling. Remove and immediately dispose of shoe covers and gloves when sampling is complete.
- Avoid disturbing or tracking dust between locations by identifying and clearly marking all sampling locations upon arrival at the sampling site, and avoiding walking through or disturbing the marked areas prior to sampling.
- The appropriate template size should be identified within the project Sampling and Analysis Plan (SAP). Templates may be made of reusable aluminum or plastic or disposable cardboard or plastic. All templates should be thin (<3 mm (1/8 in.)), be able to lie flat, and must have accurately known inside dimensions. If reusable templates are employed, they must be decontaminated between sample (or subsample) locations.
- If appropriate, the solvent (including the required grade) in which the contaminants are most soluble should be identified.
- Sample containers should not be opened until needed to collect each sample. Sample containers for source samples or samples suspected of containing high concentrations of contaminants should be placed in separate plastic bags immediately after collecting, preserving, tagging, etc.
- If possible, background samples and source samples should be collected by different field teams. If different field teams cannot be used, all background samples should be collected first and placed in separate ice chests or shipping containers. Samples of waste or highly contaminated

samples should never be placed in the same ice chest as environmental samples. It is good practice to enclose waste or highly contaminated samples in a plastic bag before placing them in ice chests. Ice chests or shipping containers for source samples or samples suspected to contain high concentrations of contaminants should be lined with new, clean, plastic bags. In general, sample collection activities should proceed progressively from the suspected least contaminated area to the suspected most contaminated area.

- If possible, one member of the field team should take all the notes, fill out sample tags, field sheets, etc., while the other members collect all of the samples. The exact areas sampled should be recorded in the logbook.
- Adequate field control samples should be collected. For vacuum and wipe samples, a blank is mandatory to identify potential interferences from the filter/gauze, solvent (wipe only), or sample containers.

C.7.4 Sampling methods. The following are sampling instructions for the most common techniques for collecting surface samples.

C.7.4.1 Surface wipe sample.

C.7.4.1.1 Applicability. This method of monitoring surficial contamination is intended for nonvolatile species (e.g., PCBs) on nonporous surfaces (e.g., metal, glass). Sample points should be carefully chosen and should be based on site history, manufacturing processes, personnel practices, obvious contamination, and available surface area.

C.7.4.1.2 Method summary and equipment. Surface wipe sampling methods vary and are dependent on the data objectives.

C.7.4.1.3 Sampling procedure. A generalized procedure is presented here for reference.

- C Place a clean, appropriately sized square template cutout over the area to be sampled (Toxic Substances Control Act (TSCA) requires 100 cm²). Secure the template to avoid any shifting during the sampling activity. Do not touch or walk on marked areas. Areas should be documented by a drawing of the floor plan, if applicable, in the field logbook. Unique sample number identifiers should be included within the drawing.
- C Remove a gauze pad from the box of gauze using decontaminated tongs (filter paper may also be used). Be sure to use a new pair of surgical gloves.
- C Soak the gauze or filter pad in appropriate solvent.
- C Using a decontaminated pair of tongs, wipe the area framed by the template cutout with the moistened gauze in one direction.
- C Without allowing the gauze to contact any other surface, fold the gauze with the exposed side in, and then fold it again to form a 90-degree angle in the center of the gauze.
- C Place the gauze in an amber laboratory sample container, angle first, and replace the container cap.

- C Secure the cap tightly.
- C Label the sample bottle with the appropriate sample label. Be sure to complete the label properly and clearly, addressing all categories or parameters.
- C Place a filled sample container on ice immediately, if desired.
- C Complete all chain-of-custody documents and record information in the field logbook (see Instruction F-1, "Documentation," Appendix F). Prepare the samples for shipment (see Instruction F-2, "Packaging and Shipping Procedures," Appendix F).
- C Mark the area of the cutout using a paint stick, if possible.
- C Record the location data, station number, sample time, date, and names of the sampling crew in the field logbook or log sheet for each wipe sample. In addition, document the sampling locations by including a drawing or dimensioned sketch in the field logbook or log sheet if the sampled area cannot be marked by a paint stick or if locating the area from the field notes would be difficult.
- C Dispose of generated waste material properly.

C.7.4.2 Chip/core sample.

C.7.4.2.1 Applicability. This method of monitoring surficial contamination is intended for nonvolatile analytes (e.g., PCBs) on porous surfaces (e.g., cement, brick, wood). Suggested sampling points include floors near process vessels, storage tanks, loading docks, etc.

C.7.4.2.2 Method summary and equipment. Samples from porous surfaces can be obtained by breaking up a designated surface with a chisel, brushing up the chipped pieces, and transferring the sample into a bottle. A core sample can also be collected using appropriate power tools. However, most confirmatory sampling requires that only the upper 6 mm (1/4 in.) of the media be sampled. Core samples may require further sample handling (i.e., sawing) to isolate this portion of the sample for analysis, or may risk diluting contaminants that may be present only in the upper 6 mm (1/4 in.) if the sample is analyzed as a whole, and are therefore discouraged.

C.7.4.2.3 Sampling procedure. Once the sample location has been determined, measured, and marked off, sample collection can begin as follows:

- C Place a clean, appropriately sized template cutout over the area to be sampled. The template may be square, U-, or L-shaped, as appropriate to the area under assessment. Secure the template to avoid any shifting during the sampling activity. Do not touch or walk on marked areas. If applicable, areas should be documented by a drawing of the floor plan in the field logbook. Unique sample number identifiers should be included within the drawing.
- C Use a decontaminated chisel and hammer to break up the surface to be sampled (TSCA requires 100 cm²). Avoid scattering pieces. Chip the area to less than 6 mm (1/4 in.) in depth.
- C Record the depth at which the chips were taken.
- C Collect the chipped pieces using new clean gloves and a pair of decontaminated tongs.

- C Transfer the sample directly into the sample bottle.
- C Secure the cap tightly.
- C Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Place the filled sample container on ice immediately.
- C Complete all chain-of-custody documents and record in field logbook (see Instruction F-1, "Documentation," Appendix F). Prepare samples for shipment (see Instruction F-2, "Packaging and Shipping Procedures," Appendix F).
- C Decontaminate sampling equipment after use and between sampling locations.

C.7.4.3 Vacuum dust sample.

C.7.4.3.1 Applicability. This sampling method is used to monitor surficial contamination for carpeted or noncarpeted areas. Sampling is typically intended to assess residential or industrial dust contamination associated with metals species (e.g., lead). Sample points should be carefully chosen and should be based on traffic areas, dust migration pathways, potential exposure of most susceptible personnel (e.g., the bedroom of youngest/oldest resident), obvious contamination, and available surface area. Undisturbed areas such as an attic may be used to assess historic dust concentrations.

C.7.4.3.2 Method summary and equipment. Surface dust samples are vacuumed onto a filter with the use of a calibrated air monitoring pump. Samples may be a composite of subsampled areas or individual samples taken from each location, depending on the project data objectives. All sampling locations should be clearly defined within the Field Sampling Plan portion of the SAP.

C.7.4.3.3 Sampling procedure. A generalized procedure is presented here for reference.

- C Place a clean, appropriately sized template cutout over the areas to be sampled (e.g., 0.09 to 0.03 m² (1 to 3 ft²)). The template may be square, U-, or L-shaped, as appropriate to the area under assessment. Secure the template to avoid any shifting during the sampling activity. Do not touch or walk on marked areas. Areas should be documented by a drawing of the floor plan in the field logbook. For composite samples, areas should be numbered to depict the sequence of sample collection. For individual samples, unique sample location identifiers should be included within the drawing.
 - (1) For carpeted areas, suggest placing templates at any high-traffic area in the room (e.g., immediately inside doorways into room).
 - (2) For noncarpeted (hard-surface) areas, suggest placing templates in areas where dust is likely to migrate (e.g., immediately adjacent to wall or at the edges of the room).
- Connect the inlet port of a portable, battery-operated air monitoring pump (capable of maintaining a flow rate of 3.0 L/min through a filter cassette) to tubing sized to fit tightly on the outlet side of the air monitoring filter cassette. Pump flow must be calibrated to the project-specified flow rate per manufacturer's instructions using a soap bubble airflow meter or calibrated rotameter.

- Connect the collection nozzle (i.e., stainless steel or carbon-impregnated plastic machined/molded to form a thin rectangular opening of 1.3 mm by 1.2 mm (1/2 in. by 3/64 in.) for the sampling end and the other machined/molded to accept tubing) to tubing sized to fit tightly on the inlet side of the filter cassette.
- C Hold the vacuum in the sampling position above the template, turn on the air monitoring pump, and ensure the flow rate is at 3.0 ± 0.2 L/min (or as specified in project SAP).
- Execute the vacuuming technique as follows:
 - (1) First pass: Hold the collection attachment at a 45-degree angle to the surface and move from one side of the template to the opposite side. The rate of movement should be approximately 1.5 to 2 seconds for each stroke. Continue in the same direction until the entire area has been vacuumed.
 - (2) Second pass: Repeat the above procedure in a direction 90 degrees from the first pass.
 - (3) Third pass: Repeat this procedure in the same direction as the first pass.
- C Remove the filter (dust) cassette from the tubing attachments and secure with end caps.
- C Label the filter (dust) cassette with pertinent sample information as defined in Instruction F-1, Appendix F.
- C Complete all chain-of-custody documents and record information in the field logbook (see Instruction F-1, "Documentation," Appendix F). Prepare the samples for shipment (see Instruction F-2, "Packaging and Shipping Procedures," Appendix F).
- C Record all measurements onto a drawing of the floor plan, including the location data, station number, sample time, date, and names of the sampling crew, in the field logbook or log sheet for each vacuum sample.
- C Dispose of generated waste material properly.

C.7.4.4 Sweep sample.

C.7.4.4.1 Applicability. This method of monitoring surficial contamination is intended for nonvolatile analytes (e.g., PCBs) in the residue found in porous (e.g., asphalt) or nonporous (e.g., metal) surfaces. Sweep sampling allows collection of dust/residue that may help in the assessment of contaminant determination and delineations. Sample points should be carefully chosen and should be based on traffic areas, dust migration pathways, potential exposure personnel, obvious contamination, and available surface area. Undisturbed areas such as an attic may be used to assess historic dust concentrations.

C.7.4.4.2 Method summary and equipment. Dust and residue samples can be collected with a bristle brush and dustpan in places where solvents cannot be used or when large amounts of dust/residue make wipe samples impractical.

C.7.4.4.3 Sampling procedure. Once the sample location has been determined, measured, and marked off, sample collection can begin as follows:

- C Put on clean, chemical-resistant gloves (separate pair for each location).
- C Place a clean, appropriately sized template cutout over the area to be sampled. Templates may be square, U-, or L-shaped, as appropriate to area under assessment. Secure the template to avoid any shifting during the sampling activity. Do not touch or walk on marked areas. Areas should be documented by a drawing of the floor plan in the field logbook. For composite samples, areas should be numbered to depict the sequence of sample collection. For individual samples, unique sample location identifiers should be included within the drawing.
- C Sweep all residues from the area to be sampled into the dustpan.
- C Transfer the sample directly into the sample bottle.
- C Secure the cap tightly.
- C Label the sample bottle with the appropriate sample label. Be sure to complete the label carefully and clearly, addressing all the categories or parameters.
- C Place a filled sample container on ice immediately.
- C Complete all chain-of-custody documents and record in field logbook (see Instruction F-1, "Documentation," Appendix F). Prepare samples for shipment (see Instruction F-2, "Packaging and Shipping Procedures," Appendix F).
- C Decontaminate sampling equipment after use and between sampling locations.

C.7.5 Decontamination procedures. All nondisposable templates and sampling equipment must be decontaminated prior to its use. Field equipment should be cleaned as described in Instruction E-6, Appendix E. The sampling equipment should be placed in a plastic bag until immediately prior to use. Additional sampling devices may be needed onsite to ensure an adequate drying time.

C.7.6 Field control samples requirements. Field control samples are collected by the sampling team to determine whether the data are of suitable quality. They include blanks, replicates, and/or background samples. A detailed discussion of field control samples may be found in Instruction G-2, Appendix G, and is summarized in the following sections as they are applied to surficial sampling.

C.7.6.1 Duplicate/split samples. True duplicate/split samples cannot be collected in a surficial or dust/soot sampling program. The sampling medium (i.e., filter or gauze) used to collect the sample cannot be divided to obtain a duplicate/split sample because the contaminants will not be spread evenly on the sample medium. The same surface area cannot be sampled a second time to obtain a duplicate/split sample because the first sample will remove the contaminants from the area under assessment. Collecting a sample from an area adjacent to the first sampling area is a viable alternative for collecting a duplicate/split sample. However, the sample is not a true duplicate/split sample and the contaminant concentrations in the samples from the adjacent area may not be the same.

C.7.6.2 Blank samples. Vacuum and wipe blanks are samples collected in the field to determine if any interference has been caused by the sample collection materials (i.e., filters/gauze, solvent (wipe only), or sampling equipment). These blanks are obtained by preparing the sample medium for sampling, placing the solvent on the gauze if applicable, and placing the sampling medium in the sample containers, or securing

the sample for shipment as directed within the instruction. The sample medium does not contact any sampling surface.

C.7.6.3 Background samples. Background samples are recommended to be taken in conjunction with chip/core samples. Background samples should be taken using the same procedures used to obtain the field samples. The samples should be obtained from an uncontaminated area of the same matrix used to collect the field samples. The rationale for collecting background samples is to determine if there are any interferences inherent in the porous matrix.

C.7.6.4 Rinsate blank samples. Rinsate samples consist of reagent water collected from a final rinse of surfaces after decontamination procedures have been performed. The purpose of the rinsate samples is to determine the thoroughness of the decontamination procedures performed.

C.7.7 Documentation requirements. Bound field logbooks should be used for the maintenance of field records. Record all aspects of the site setup, sample collection and handling as outlined in the preceding sections and in Instruction F-1, Appendix F.

C.8 Air and Soil Gas Sampling

C.8.1 Air sampling. This section addresses the aspects of gas phase sampling and analysis for HTRW projects. This type of sampling can involve four categories of sample collection and measurements: soil gas in situ or extractive; surface area emission flux; point source emissions or remediation process streams, including in-place control and containment systems; and ambient air at the site perimeter or at off-site receptor locations. The media sampled for soil gas or surface area emissions are typically gaseous phase samples. Point source, process streams, and ambient air sampling can involve either gaseous phase samples or particulate matter.

C.8.2 Soil gas sampling.

C.8.2.1 Scope and application. Soil gas monitoring of the vadose zone is used to measure characteristics of the soil atmosphere as an indirect indicator of contamination in or below the sampling horizon. The information may be used for health and safety purposes, to detect and monitor migration of volatile contamination of soils within the vadose zone, to support the design of a soil vapor extraction system, to assess the extent of ground water volatile organics contamination, to verify underground storage tanks integrity and monitor for any subsurface discharges, and to aid in locating ground water monitoring wells, extraction wells, recovery trenches, etc. It is also used for general reconnaissance, and as a screening technique when large areas are being evaluated that have little or no information available on past waste disposal practices. The primary limitation to this type of sampling is that it is not a stand-alone technique, and additional sampling of environmental media is necessary to determine the source and extent of contamination. Soil gas samples may be analyzed onsite, or samples containerized and shipped to a laboratory for offsite chemical analyses. The overall effectiveness of a soil gas sampling method to depict subsurface conditions accurately is dependent on several factors, including soil permeability; infiltration moisture; barometric pressure changes; volatility of the contaminant; the presence of any underground obstacles or conduits, pavements, or other features affecting pathways; the presence of interfering chemical compounds, etc. Soil gas sampling technology is most effective in mapping low-molecular-weight, halogenated, or aromatic hydrocarbons that possess high vapor pressures and low aqueous solubilities (e.g., benzene, toluene, trichloroethylene, trichloroethane, vinyl chloride, etc.)

C.8.2.2 Sampling strategies. Sampling strategies are developed by the project team to satisfy project-specific data needs that are identified during the HTRW technical planning process. Sampling strategies will vary based on the intended purpose of the soil gas survey; and they are significantly influenced by such factors as site physical constraints, soil types and stratigraphy, background information available, and type of contamination, to name a few. When soil gas sampling is used to optimize monitoring wells or soil boring locations or monitor the integrity of underground storage tanks, a sampling strategy based on a judgmental or biased approach is recommended. However, when soil gas sampling is used for general site reconnaissance, the use of a statistical sampling method (i.e., a systematic grid approach) is typically used. Many projects use a combination of these sampling strategies. For instance, an initial sampling may be done by a predetermined regularly spaced grid pattern to identify presence of contamination, followed by a judgmental or close, irregularly spaced grid pattern approach to refine the delineation of the contamination detected. Grid spacing shape and size should be based on the project objectives and allowable uncertainty in the decision-making process, but be flexible enough to allow modifications in the field to account for site characteristics, or generated results. The technical planning process that results in the development of project soil gas sampling strategy is critical because of the difficulty in acquiring representative soil gas samples.

C.8.2.3 Sampling locations. Sampling at hazardous waste sites is usually conducted in an attempt to discover contamination and to define its extent and variability. With such an objective, it is most logical to choose sample locations that will yield the most information about site conditions. As noted in the

preceding section, a soil gas sampling survey can be conducted by following random, systematic, or biased sampling strategies. The same information used to select the sampling strategy is used to choose the soil gas sampling locations. Sample locations must account for a variety of physical properties of the soil, including grain size, cohesiveness, organic matter, moisture content, geographic fractures, and overall soil permeability. In addition, the properties of the chemical contaminants must also be considered, including volatility, solubility or immiscibility in water, and degradation potential. Appropriate sampling depths are determined by assessing these factors and the depth to ground water, the source, soil stratigraphy, and features that enhance or impede the movement of the soil gas. Multiple depth sampling is also an option, when complex geologic settings are encountered.

C.8.2.4 Sampling techniques and sample types. Soil gas samples may be generated in conjunction with an active or passive sampling system. The samples themselves may be a whole air sample or a sorbent sample composed of an absorbent/adsorbent medium that collects contaminants during a specified time frame.

C.8.2.4.1 Active soil gas sampling system. An active soil gas sampling system involves the forced movement of bulk soil gas from the vadose zone to a collection device through a probe or similar apparatus by the influence of a vacuum pump. The air within the system may be monitored real-time through a sample port with an appropriate detector (e.g., photoionization detector or flame ionization detector) or coupled directly to an analytical system for direct monitoring readout documentation. Active soil gas systems may also be sampled with a gas-tight syringe for onsite gas chromatograph analysis, or whole air samples collected in tedlar bags, glass bulbs, summa canisters, or other containment devices for subsequent onsite or offsite analyses. Refer to Figure C-22 for an illustration of a summa canister for the collection of whole air samples. The active soil gas sampling system may also be configured to collect a sorbent sample. Refer to Figure C-23 for a schematic of a sorbent media cartridge for the collection of sorbent samples. In this way, the probe is connected to a collection device designed to extract and trap chemical contaminants from the airstream by adsorption. This technique is especially useful when very low-level contamination is present that is below the

instrument sensitivity capabilities for whole air samples, and preconcentration of the contaminants onto the adsorbent medium is necessary. Some sorbent media can also be used to segregate interfering compounds (e.g., reactive or oxygenated organic compounds), for the medium can be treated or designed so the inferences will not be adsorbed or easily desorbed from the collection medium. Sorbent samples are also beneficial when the chemical contaminants are more amenable or more efficiently removed and detected by extraction techniques. The collection medium is typically activated charcoal, silica gel, activated alumina, various porous polymers, or molecular sieve adsorbents that have been prepared by thermal (or solvent) desorption treatment. Limitations in the use of sorbent samples include interactions between the

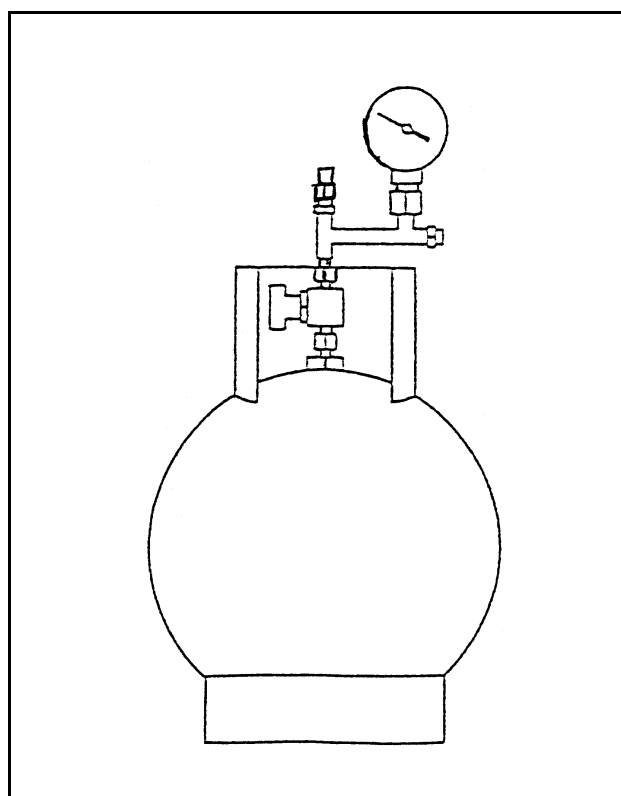


Figure C-22. Rigid whole air collection canister (summa canister)

contaminants and the sorption medium, the release of artifacts during the desorption process, and high humidity, which can significantly impact the adsorption efficiency of the sorption medium. Advantages in using an active soil gas sampling system include the quick turnaround for data and the ability to tailor the survey as it progresses. Limitations of an active soil gas system include its cost compared to that of passive techniques and its susceptibility to meteorological effects, i.e., false negative results when rainfall or snowmelt occurs. This is due to infiltration water driving the contaminant vapors ahead of the infiltrating front and drawing clean atmospheric air into the zone to be sampled. Driven probes also tend to degrade the natural soil permeability around the body of the probe due to soil compaction during probe insertion. This may severely impede the active soil gas flow in moist, heavy clay soils.

C.8.2.4.2 Passive soil gas sampling system.

A passive soil gas sampling system entails placing a collection device in the subsurface or on the surface of the ground and allowing the atmosphere in the device to come to compositional equilibrium with the soil atmosphere. A passive soil gas sampling system may be used to collect whole air samples. This approach may be used to monitor contaminant emissions for health and safety purposes (i.e., methane emissions from a landfill) and is discussed in Section C.8.3. More commonly, the passive soil gas sampling techniques are used in conjunction with a sorbent medium. Several varieties of these collection devices exist, with slightly different configurations. However, the basis for sampling is the same, in that it is the passive movement of contaminants in soil to a sorbent medium contained in a collection device over a specified period of time. Several types of sorption media are available, which, due to their adsorption properties, will reduce the contaminant concentration directly adjacent to the device. This induced concentration sink helps maintain continuous migration of contaminants from the vadose zone toward the collection device by diffusion and mass transfer. The rate of contaminant migration is limited by many of the same factors affecting the active soil gas sampling techniques. These include soil physical characteristics and the physical and chemical properties of the contaminants. In addition, caution must be exercised during installation or backfilling to avoid cross-contamination of the sorbent media. Typical residence times for the collection devices range from several days to weeks to complete. The passive-sorbent sample system is not recommended when the ground is frozen or when saturated soil conditions exist. Advantages to the use of a passive soil gas sampling system include its nominal cost, its lower susceptibility to meteorological changes, and the addition of less volatile contaminants that may be analyzed. Limitations include the following: time frames for data retrieval are

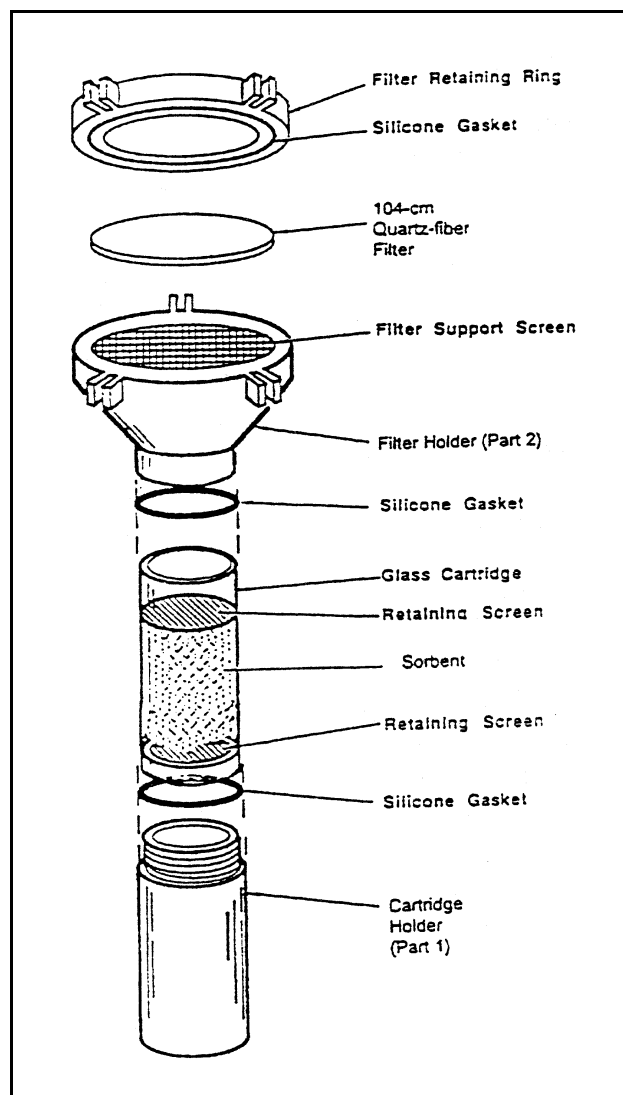


Figure C-23. Sorbent media (resin) cartridge

long, which necessitates the need for more samples for thorough coverage, and it is not appropriate for use with soil vapor extraction system design.

C.8.2.5 Sample preservation and handling. Methods for preservation of whole air and sorbent samples are relatively limited and are generally intended to retard thermal and photodegradation. Preservation methods for whole and sorbent samples are typically avoidance of heat or light. This may be as simple as placing samples potentially exposed to light (i.e., tedlar bags) in dark plastic garbage sacks, and keeping out of direct sunlight. Sorbent samples preservation will vary based on the sorbent medium used. Therefore, follow any procedures identified by the vendor or manufacturer.

C.8.2.6 Collection of adequate field control samples. Field control samples are collected by the sampling team to determine whether the data are of suitable quality. They may include blanks, replicates, and/or background samples (atmospheric blanks). The application, type, and frequency of field control sample acquisition should be based on the purpose of the soil gas survey and the associated data quality requirements. Field control samples taken in conjunction with soil gas sampling techniques are typically limited to a variety of field blanks to assess potential cross-contamination sources and contribution. Field blanks used include trip (travel) blanks, sample container blanks, and sample probe blanks. Field replicates may be taken. However, due to the difficulty in acquiring representative replicate air or adsorbent samples, taking field replicates is not commonly practiced. A detailed discussion of field control samples is contained in Instruction G-2, Appendix G.

C.8.2.7 Sampling methods. Due to a variety of configurations for passive soil gas sampling methods, defer to the individual manufacturer's installation and instruction manual. The following encompasses general procedures for an active soil gas sampling system. Additional procedures may be necessary based on the manufacturer's specifications. Method Reference: ASTM D 5314.

C.8.2.7.1 Applicability. Active soil gas sampling systems are widely used as a preliminary site characterization tool for the initial field activity of a site investigation. Active and passive soil gas sampling systems are an economical and efficient method for obtaining information on potential subsurface contamination without the expense of drilling and its related waste cuttings disposal costs.

C.8.2.7.2 Method summary and equipment. The active soil gas sampling system involves sampling devices that are directly inserted into the soil to be sampled without drilling/excavation, or into the soil ahead of the auger or drill bit if performing deep sampling or vertical profiling. The active soil gas sampling consists of advancing a sampling device into the subsurface by applying static pressure, impacts, or vibration or any combination thereof to the aboveground portion of the sampler extensions until the sampler has been advanced its full length into the desired soil depth or strata. The equipment generally used to drive the sample probe is small and relatively compact allowing for mobility around the site and access to confined areas. The probe is then retracted slightly to remove the expendable drive point or open a sample port and create a void where soil gas may enter the sample probe. A vacuum is drawn on the system with a pump to induce the flow of soil gas through the sample probe to the surface where whole air or sorbent samples may be acquired.

C.8.2.7.3 Active soil gas sampling procedure. The sampling procedure is as follows:

- C Assemble decontaminated active soil gas sampling probe device, consisting of a drive point, point holder, a hollow extension pipe, or other equipment as specified by a manufacturer. Push the apparatus into the ground to collect samples (Figure C-24).

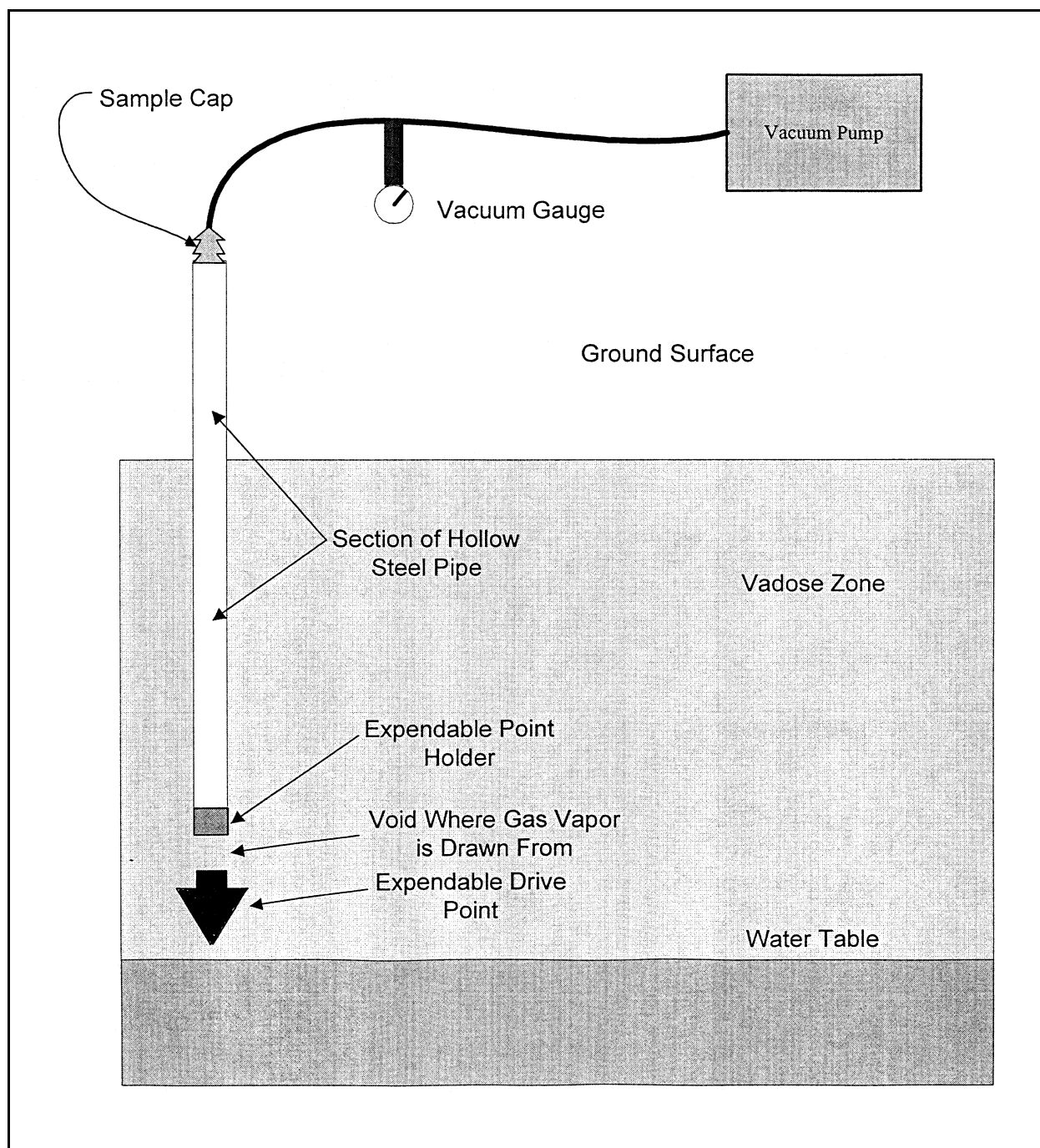


Figure C-24. Active soil gas apparatus

- C Advance the sample probe by applying static pressure, impacts, or vibration or any combination thereof to the aboveground portion of the sampler extensions until the sampler has been advanced its full length into the desired soil depth or strata (typically 1.5 to 3 m (5 to 10 ft)).
- C Sample probes may be fitted with detachable drive tips, which become removed from the steel pipe when the probe is retracted.

- C Attach the flexible tubing with appropriate sampling port or sorbent media cartridge, followed with additional flexible tubing to a vacuum pump.
- C Extract gas through the probe via the vacuum pump. Five probe volumes should be extracted prior to sampling. A qualitative check for leaks or short circuits is performed by monitoring the vacuum and flow rates. A drop in vacuum or too low a vacuum may indicate system problems. Quantitative leak checks may also be used to verify that the system performance is acceptable at the highest vacuum required by the project. Project-specific acceptance criteria should be established when necessary.
- C Begin sampling with appropriate sample containers through a sampling port set between the probe and the pump. These may include real-time monitors (photoionization detector or flame ionization detector), gas-tight syringes, tedlar bags, summa canisters, etc., for a whole air sample. Or preset the appropriate sorbent media and cartridge at the same location between the probe and the vacuum pump.
- C Close off appropriate valves for sample containers. Samples should be protected from heat and light.
- C Label the sample containers. Complete the label completely and clearly, addressing all the categories and parameters.
- C Complete chain-of-custody documents and field sheets and record in the logbook (see Instruction F-1, "Documentation," Appendix F).
- C Samples not analyzed immediately should be prepared for shipment to the laboratory (see Instruction F-2, "Packaging and Shipping Procedures," Appendix F).
- C Decontaminate the equipment following each probe or sample.

C.8.2.8 Decontamination procedures. All sampling equipment must be disposable or decontaminated prior to its use. Sampling equipment should be decontaminated as described in Instruction E-6 (Appendix E).

C.8.2.9 Documentation requirements. Bound field logbooks should be used for the maintenance of field records. Record all aspects of the site setup and sample collection, preparation, and handling, and all field analytical reportables (i.e., calibration data, sample and QC results, chromatograms, etc.) as outlined previously and in Instruction F-1, Appendix F.

C.8.3 Surface emission flux measurements

C.8.3.1 Scope and application. Surface emission flux rate sampling for gaseous compounds involves the isolation of either an "as-is" surface area or a prepared "scraped" area to collect and quantify the release of contaminants of concern. A flux chamber is used to cap the surface area being evaluated while the chamber is continuously swept by the injection of an inert gas or air. The resulting gaseous mixture is then sampled and analyzed. The rate of contaminant emission from the source area is calculated based on the flow rate of the incoming inert gas and the concentrations of contaminants found in the mixed gas sample. This type of sample collection and measurement is often selected when indoor or localized ambient air contamination is of concern due to contaminant migration from known or suspected HTRW sites. Emission

flux data are collected to provide more accurate site-specific contaminant emission data than may be obtained from predictive models. The calculated emission data can be used for contaminant fate and transport calculations, risk assessment, or determination of the rate of release to the atmosphere. In effect, this measurement may improve the accuracy of the “migration” rate from a source to the gaseous phases. The results of such measurements are expressed in units of contaminant flux rate per time (i.e., mass/area/time), most commonly reported as : g/minCm². Primary limitation of this technique is the lack of analytical sensitivity of the gas mixture due to the dilution from the injected inert gas.

C.8.3.2 Sampling strategies. Sampling strategies are developed by the project team to satisfy project-specific data needs that are identified in the HTRW technical planning process. The sampling strategy developed at a particular site will vary based on the intended purpose of the flux emission data. Flux chamber sampling strategy must address the VOC source, most likely route of travel, potential and real receptors affected by the VOC migration, and any target receptors with unique characteristics. Sampling strategies are based on subdividing areas into zones, and then sampling within each zone to assess zone variability. Many flux chamber applications and sampling strategies are either based on judgmental decisions or biased to site-specific conditions. For example, the effect of VOCs in creating an indoor air problem may necessitate the sampling of specific basement floor fractures and cracks. Also affecting the sampling strategy are the varying effects of changing meteorological conditions. The sample collection method must preserve the project concept of a representative sample. This may include maintaining sufficient duration for real-time measurements or obtaining a sufficient number of grab samples or a sufficient number of sample aliquots for compositing of time-integrated samples.

C.8.3.3 Sampling locations. Sampling locations will be determined by both the site-specific characteristics and the nature of the contaminants of concern. For indoor air issues, the sampling locations will likely be selected based on the receptors (buildings/structures/occupants) of concern. For emission flux data to be used for risk assessment or site-specific emission modeling, sampling locations should be located based on known or suspected contaminant sources and the most likely route of migration. For instance, migration may be determined through soil or concrete slab fractures, fuel emissions based on the known location of an underground storage tank or transport pipe, landfill cover deficiencies or openings, specific areas of a lagoon system, etc.

C.8.3.4 Sampling techniques and sample types. Figure C-25 shows a schematic of a flux chamber apparatus. A similar device that enables the user to sweep inert gas continually over a surface area and collect liberated volatile compounds from the isolated head space may be used. The specific application and contaminants of concern will usually dictate the design features of the sampler. Design parameters address the relative volume of the head space of the steady-state flux chamber and any special features for flotation, such as when evaluating a liquid source area. The volatiles swept from the flux chamber headspace can be monitored directly using field instruments or measurement devices, a sample can be collected from a series of grab samples and analyzed onsite, or a sample can be collected as aliquots and composited to constitute a time-integrated sample. In general, the liquid or solid surface is selected and prepared for the flux chamber application, as necessary. The characteristics of the sampling equipment and procedures are determined by the source media, the contaminants of concern, the detection limit measurement objectives, and the method of sample collection or detection. Flux chambers utilize an inert sweep gas from compressed cylinders of nitrogen or “zero air,” or a purification system established for use with ambient air. For the latter approach, the effectiveness of the cleaning step should be verified. Refer to ASTM D 5314 for additional guidance on this type of sampling.

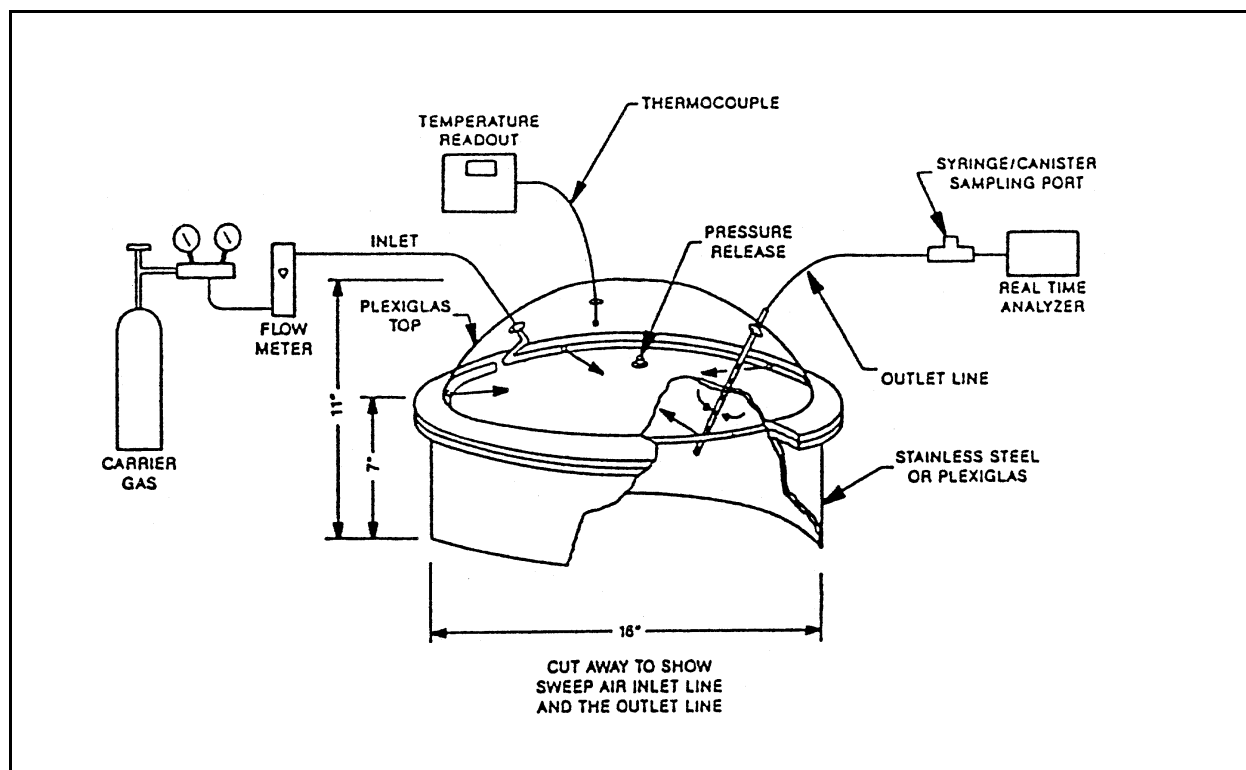


Figure C-25. Flux chamber apparatus

C.8.3.5 Sample preservation and handling. Methods for preservation of whole air and sorbent samples are similar to those identified for soil gas samples (Section C.8.2.4). Preservation of some absorption media samples may include cooling to $4^{\circ}\text{C} \pm 2^{\circ}\text{C}$ to avoid contaminant loss or degradation. Glass collection cartridges may also be packed in metal containers to avoid breakage and photodegradation of contaminants.

C.8.3.6 Collection of adequate field control samples. Field control samples are collected to verify the integrity of the sampling system as interference-free, to evaluate reproducibility of the sampling procedures, and to determine whether the data are of acceptable quality. Field control samples include a variety of blanks, system checks, and the acquisition of replicate samples.

C.8.3.6.1 A system check should be done that isolates the flux chamber from the emission surface area, usually by inserting a sheet of inert and impermeable material on top of the surface area during a flux rate determination. This is also considered a field method blank. For whole air samples, method blanks should include collection of the sweep gas directly into a flexible or rigid container. This blank verifies sweep gas integrity.

C.8.3.6.2 For surface emission sampling, the flux chamber effluent may be split to collect duplicate whole air samples or duplicate media absorption to evaluate method precision. These samples may be composited from multiple grab aliquots, or successive grab samples taken by an emission extraction tee tube. For media absorption duplicates or split whole air samples, the flow rate and sampling times for each individual aliquot collected must be accurately measured and recorded. Audit gas standards can also be used

to evaluate system measurement performance but can add significant costs to the sampling and analysis program.

C.8.3.7 Sampling methods. Several varieties of devices may be configured to obtain a surface emission measurement. Time-integrated samples are collected for subsequent contaminant identification and quantitation using sorption media or whole air samples as discussed in Section C.8.2.4.1. Based on the sampler design, specifications must be established for its use. This includes identifying all sampling and support equipment necessary; establishing SOPs for sample collection; identifying the type of samples and sample containers used; determining the type, rate, and total volume of sweep gas; and determining the volume of emissions needed to meet the detection limit requirements. Such samples can be analyzed onsite or transported offsite for analyses. The utility of whole air samples is that one sample can be analyzed in duplicate, or by using separate aliquots, several different analytical procedures for different parameters or classes of compounds can be determined. For example, a gaseous landfill emissions whole air sample is typically analyzed for chlorinated and nonchlorinated VOCs, methane, sulfur gases and atmospheric “balance gases” including O₂, CO, and CO₂. Samples may also be collected on sorption media, such as Tenax, XAD-II, etc. Refer to the appropriate EPA Compendium Methods (EPA/600/4-84/041, EPA/625/R-96/010a, and EPA/625/R-96/010b) to determine the absorption medium needed. Collection of sorbent medium samples offers the ability to concentrate contaminants of concern to achieve a lower detection limit or long-term integrated sampling. For projects for which absorption media is selected as the sampling approach, recommend using the EPA Compendium Method TO-17 (EPA/625/R-96/010b) absorbance media evaluation and performance verification procedures.

C.8.3.8 Decontamination procedures. Requirements for decontamination of flux chambers are limited to specific applications such as after initial installation or if the chamber is moved from a potentially high concentration source area to a lower concentration or a trace-level source area. During field use, decontamination is usually limited to flushing the chamber with the sweep gas, either by placing the chamber on an inert surface or after placing the chamber at the measurement location and flushing to a steady-state emission concentration. When more thorough decontamination is necessary, follow procedures established in Instruction E-6 of Appendix E.

C.8.3.9 Documentation requirements. Documentation requirements are based on the information needed to support the final emission flux calculations. Critical field data are needed from both the site and sample perspectives. Record barometric readings during sampling events. This may be accomplished with an onsite barometer or from monitoring a local National Weather Station. Also record the temperature of the source matrix. The specifications should be used to determine the flux chamber dimensions. Note that any sampler-to-surface gaskets or sealants may alter the actual area of the flux. Document any carrier and calibration gases information, including cylinder serial number, contaminant and balance gases used, contaminant concentrations and any error associated with that concentration, cylinder gas pressure, cylinder receipt and expiration date, vendor providing the cylinder gas, a description of regulator gas pressure, gas flow rate measurement devices, and gas flow rate. It is highly recommended that the gas cylinder pressure be recorded during use to document the pressure decrease relative to time usage. Some contaminant concentrations become unpredictable when cylinder pressures drop below a certain pressure. Additional information needed may be referenced from the appropriate EPA or ASTM method.

C.8.4 Point source emissions and process sampling.

C.8.4.1 Scope and application. Point source sampling for HTRW projects is normally performed due to regulatory requirements to evaluate a remediation process, or to characterize a contaminant concentration for remediation feasibility, or system design and optimization. This type of sampling includes

the collection of gaseous phase or particulate matter (PM) and PM-related compounds. Regulatory emission compliance testing will involve specified USEPA sampling and analysis procedures. System process measurements are generated to evaluate efficiency of a recovery process, to determine operating parameters during system startup, or to verify the performance requirements of an Air Pollution Control system. These system measurements should utilize the most cost-effective method that produces data of acceptable quality for the defined use. Point source emissions gas phase sampling may also be required to evaluate emissions from a localized surface area that is directed through a single exit point or a vent system.

C.8.4.2 Sampling strategies. For point source emission sampling to meet compliance requirements, the regulation and specified method should be used to define the sampling strategy. To monitor system performance or contaminants associated with a remediation process, the sampling strategy should address the most representative sample extraction points for the inlet and outlet sample waste streams. The sampling strategy for measurements involving particulate-related contaminants must address sampling inhomogeneity, particulate stratification, and sampling velocity rate to satisfy the required gaseous/particulate separation and to comply with the measurement definition of particulate matter. Sampling for PM and PM-related compounds requires sample acquisition at an “isokinetic” sampling rate. Isokinetic sampling rate is defined as the collection of a gas/particulate sample through a tapered inlet sampling nozzle at the same velocity as the sample stream.

C.8.4.3 Sampling locations. Sampling locations for compliance monitoring are defined within the appropriate method, and address both the extraction point of the sample, relative to system design, as well as the total number of extraction points. For process waste stream sampling, the sampling location will be dictated by the type of information needed, the part of the system being evaluated, and the limitations of available sampling locations. Most sampling locations and sampling points are performed according to USEPA methodologies.

C.8.4.4 Sampling techniques and sample types. Most gas phase samples and particulate matter measurements are performed using extractive sampling procedures. The sampling techniques must address representative sample acquisition, sample transport and integrity, sample conditioning (when applicable), and sample contaminant separation and collection. For the majority of such measurements, the sample is extracted from the source and pulled through a sampling train with the use of a vacuum pump. The sampling train will separate particulate matter from the gaseous contaminants. Collection of the gaseous contaminants relies on either the capture on a sorbent (resin) media or in a liquid impinger absorption. Figure C-26 depicts a typical extractive sampling system including the extraction probe, the filter, heating device, postfilter volatile contaminant collection media, and condenser (impinger) absorption for collection of other contaminants.

C.8.4.4.1 Gas phase contaminants. Point source sampling systems designed to collect VOCs can either involve a PM system or function as a gas-phase-only type of collection. Systems established to collect VOC exclusively should remove and discard any particulate matter from the gas stream using a filtration procedure that minimizes method interferences. The filtration methods may include the use of a filter as depicted in Figure C-23 or use of a glass/quartz wool plug placed at the inlet of the sampling probe. For VOC sampling, heating the extraction probe and filtration devices is not necessary unless moisture condensation will result in a method interference. The gas phase contaminants may be collected on a sorbent medium, within a specified solvent, or by collection of a whole-air sample. Methods for the determination of VOCs can be found in 40 CFR Parts 60, 61, and 266 and EPA/SW-846, Chapter 10.

C.8.4.4.2 Particulate matter (PM) and PM-related compounds. Particulate matter samples and associated data can involve determining the gravimetric mass of PM collected for a given sample volume,

or the subsequent chemical analysis of that collected PM. Most point source sampling systems are designed to collect the PM in the “front half” of the collection system, followed by the collection of semivolatile organic compounds (SVOCs) and/or metals in absorption media. Figure C-26 depicts the extraction probe followed by the temperature-controlled filter. In terms of PM, the recovery of material from the method-specified collection points from the sampling probe assembly and the front half of the filter assembly, along with the material captured on the filter, is defined as PM. The PM adhering to the surfaces of the sampling nozzle, probe liner, and filter holder front half are recovered by brushing and then rinsing the PM into a collection vessel using an appropriate solvent such as acetone, methylene chloride, toluene, distilled water, etc. The mass of the PM is determined gravimetrically after solvent evaporation by subtracting the tare weight of the filter from the final weight of the sample and filter. For semivolatiles and some metals, it is necessary to collect and analyze both the collected PM and additional parts of the collection train.

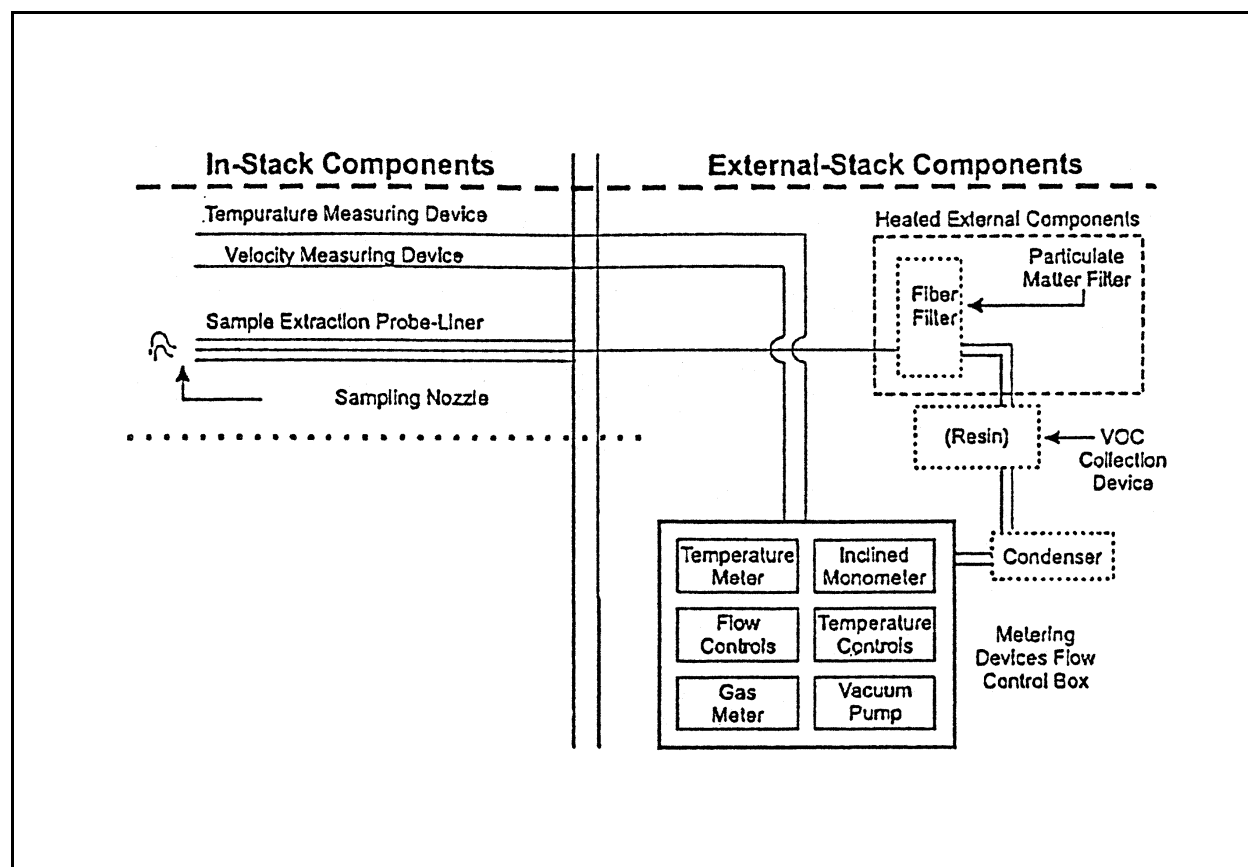


Figure C-26. Extractive sampling system

- The determination of SVOC is accomplished by recovering the probe and filter particulate and those SVOCs collected in the postfilter collection media. Commonly used collection media include Tenax and XAD-II resins. The PM is extracted using an appropriate solvent. Separately, or combined with the PM, the collection media is also extracted and the resulting extract is analyzed for the contaminants of concern. SVOC classes for HTRW projects include PCBs, dioxins/furans, PAHs, and project-specific SVOCs. The determination of both PM and SVOC can be accomplished using a single sample collection. However, it must be verified that the PM gravimetric weighing conditions specified by the method do not compromise the sample by loss

of other target analytes. Methods for the collection and analysis for these SVOCs are included in 40 CFR Parts 60 and in EPA/SW-846, Chapter 10.

- The determination of metals of interest is accomplished by recovering the probe and filter particulate and metals collected in the postfilter collection system. The metals collection system subsequent to the filter usually consists of acidic impinger solutions. When PM and metals are to be determined, the organic collection resins cannot be used in the sampling train. Methods for the determination of metals in point source emissions or process streams are included in 40 CFR Parts 60 and 266, and EPA/SW-846, Chapter 10.

C.8.4.4.3 Instrumental measurements. Most instrumental measurements of point source emissions are performed using Continuous Emission Monitors (CEMs). Applications to USEPA emission regulations require the use of CEMs. However, an equivalency program has been established to allow the use of alternative instrumental measurements proven equivalent to the regulatory specified standard. Gas phase measurements performed for purposes other than regulatory compliance may be accomplished by other means, so that the measurement DQOs are met.

C.8.4.5 Sample preservation and handling. Methods for preservation of process or point source emission samples include temperature and environmental control by method-specified procedures. In general, sample preservation of cooling to $4^{\circ}\text{C} \pm 2^{\circ}\text{C}$ is recommended for organic samples. Absorption cartridges should be covered with clean aluminum foil for sample holding and shipment for analysis. Collection media such as filters and impingers do not typically require preservation except when noted within the method.

C.8.4.6 Collection of adequate field control samples. Field control samples are collected by the sampling team as specified by the project. Most sampling methods specify collecting reagent blanks and conducting field blank recovery. A method blank is collected by assembling the entire train as for sampling and recovering the sampling train components using method procedures. For point source sampling, duplicate samples are not routinely taken. This adds considerable time and cost to the project and is seldom required from a regulatory standpoint. Acquisition of duplicate samples for PM and PM-related parameters is also discouraged due to the significant difficulty in collecting these samples.

C.8.4.7 Point source or process sampling methods. Sampling methods are categorized based on the subsequent analyses. Unique sampling protocols are used for the acquisition of volatile contaminants, particulate matter, semivolatile and metals contaminant/particulate-related matter and physical parameters. Point source compliance test methods have been codified in four 40 CFR references: Part 51, Appendix M, Part 60, Appendix A, Part 61, Appendix B, and Part 266, IX. Point source sampling done to support HTRW projects has also been included within the most recent update of Chapter 10 of EPA/SW-846. Information on these methods can be utilized by accessing the USEPA Technology Transfer Network located at www.epa.gov/ttn and using the Emission Measurement Center technical site. Other testing groups, i.e., ASTM, have issued similar test methods that may be considered alternative sampling methods. Gas phase contaminants and physical characteristics are often measured by field instruments when long-term sample monitoring or a high number of sample measurements are required. Instrumental methods available for gas phase measurements are typically CEMs. Performance specifications, which qualify the applicability of the selected CEM to an emission, are found in 40 CFR Parts 60 and 266. Technical direction and operating performance requirements for CEMs used for operational monitoring can be found in 40 CFR Part 60, Appendix F.

C.8.4.8 Decontamination procedures. For most point source emission and process streams sampling, sampling train components should be thoroughly cleaned in a laboratory environment, using prescribed or project-defined protocols.

C.8.4.9 Documentation requirements. For all point source emission and process stream sampling methods the documentation of a considerable amount of sampling data is required. Methods for PM and PM-related contaminants require the periodic recording of operational data and sampling train parameters. Refer to National Source Performance Standards 40 CFR 60 (NSPS) Method 5 and other PM-related methods to provide field sampling data sheets outlining the required parameters to be recorded.

C.8.5 Ambient air sampling.

C.8.5.1 Scope and application. Ambient air measurement for HTRW projects can involve onsite, site perimeter, or offsite sampling locations. The measurements may involve particulate matter, gaseous contaminants, or meteorological parameters. With the exception of meteorological monitoring, onsite air measurements are typically performed for worker health and safety purposes, and the requirements are specified in the project site safety and health plan. USACE guidance to determine the applicability of this type of sampling may be referenced from EP 1110-1-21. The site perimeter and offsite air measurements are typically performed for regulatory compliance, as a result of an Air Pathway Analysis, to assure nearby public health and safety, to confirm effectiveness of process and onsite emission controls, and to comply with project requirements.

C.8.5.2 Sampling strategies. Sampling strategies are developed by the project team to satisfy project-specific data needs that are identified in the HTRW technical planning process. The sampling strategy developed at a particular site must include permanent and mobile sampling site collections, coordination of sampling locations with meteorological conditions and site activities, contingency sampling based on survey or optimized ambient air monitoring, and sampling based on site-specific sensitive receptors, terrain features, etc. Sampling strategies are often limited by site-specific characteristics and activities that vary during the project. Refer to EM 200-1-5 or EPA/451/R-93/007 for information on the development of ambient air monitoring sampling strategies.

C.8.5.3 Sampling locations. Sampling locations for site perimeter or offsite ambient air sampling are dependent on project data objectives. In the simplest form of perimeter monitoring, a single sample at a downwind location would require periodic sampling during pertinent activities. If the objectives include calculating a net site contribution, then a corresponding upwind sample will be required. If short-term (less than 24-hour) sampling is required, a mobile sampling apparatus that is moved to accommodate the changing downwind location or a minimum of four permanently established sampling locations which are operated only periodically will be necessary. Greater limitations are usually experienced for offsite sampling locations and frequencies than at the perimeter due to location accessibility, power supplies, and neighborhood acceptability and environments. For some longer term HTRW projects a real-time perimeter monitoring system may be most feasible. An alternative "sector monitoring" sampling strategy may be applicable. Offsite sample locations may pose additional difficulties due to location accessibility, power availability, and community acceptance.

C.8.5.4 Sampling techniques and sample types. A variety of sampling and measurement techniques are available that address ambient air monitoring at HTRW project sites for general classes of VOCs, SVOCs, particulate matter, metals, and meteorological parameters.

C.8.5.4.1 Gas phase contaminants. Gaseous ambient air contaminants can be measured directly with onsite instrumentation or by sample collection and analyses. Collection of gaseous ambient air VOC components of interest is typically accomplished by collecting a “whole-air” sample within a flexible or rigid container or by absorption of the compounds within a collection resin. Figure C-22 depicts a summa canister, which has an internal surface that maintains sample component stability. Figure C-23 depicts an absorption resin collection cartridge, which collects and concentrates the VOCs of interest. Several of the Compendium TO-methods specifically address VOCs including TO-1, -2, and -14 (EPA/600/4-84/041), -16, and -17 (EPA/625/R-96/010b). These methods should be selected to satisfy project-specific components of interest, the applicability of the method to site-specific conditions, and the ability of the method to provide project-required data quality objectives.

C.8.5.4.2 Particulate matter (PM) and related compounds. The collection of PM in ambient air is typically accomplished by passing the sample through a preweighed filter. The filter is subsequently reweighed for a quantitative determination of the PM. PM in ambient air is categorized as total suspended particulate or some size fractionation. These fractionations range from a PM less than 10 microns (PM-10) to a lesser size such as PM-2.5. To determine the appropriate categories, the PM-10 or PM-2.5 is quantified gravimetrically as mass per volume after separation from the larger total PM. Similar to point source PM measurements, ambient air PM can be collected to determine SVOCs or metals. A typical total suspended particulate matter collection device is depicted in Figure C-27.

- SVOCs sampling includes the collected PM fraction of the sample, and the fraction that passes through a filter media and is collected on an appropriate sorption medium. Most SVOC collections are performed using a filter followed by a sorbent media of polyurethane foam or XAD-II resin. The SVOC classes often required for HTRW projects include PAHs, pesticides, PCBs, dioxins/furans, etc. When projects require more than one of these SVOC classes, recommend that procedures for sample collection, recovery, preparation, and analysis be combined. Also recommend that project-specific SOPs be generated to assure that the procedures meet project sensitivity and QC requirements.

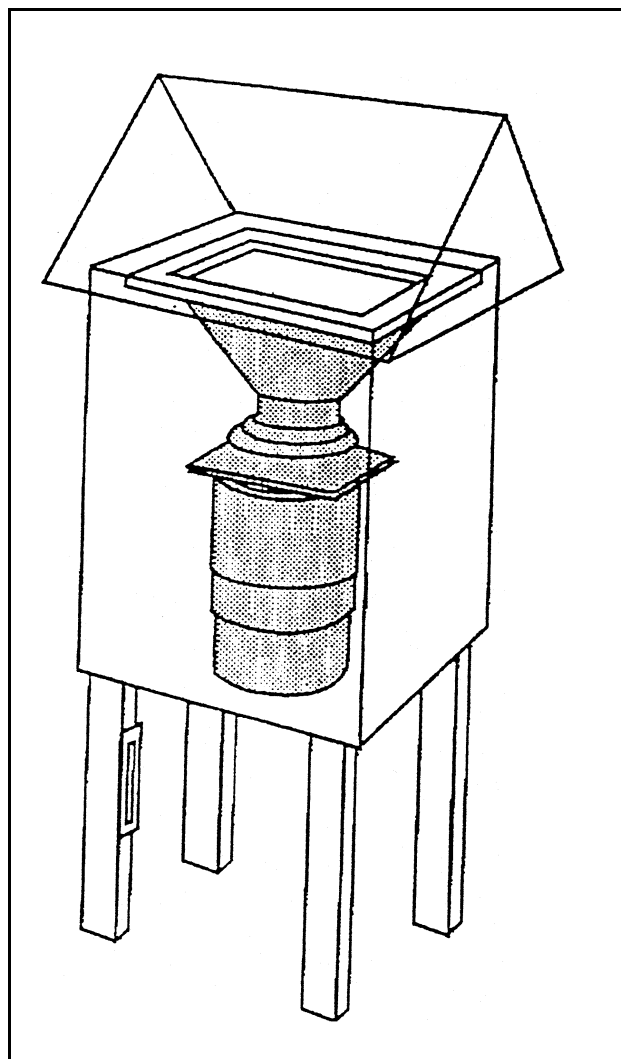


Figure C-27. Total suspended particulate matter sampling system

- Sampling and analysis for metals in ambient air are usually accomplished by using the total suspended particulate collected sample after reweighing. A fraction of the collected filter/PM is digested for the appropriate analytical procedure. The selection of the collection filter media must be performed with care relative to the required metal measurement method detection limit and the method-required filter blank correction. Factors including the metals of concern and the amounts of their presence in the blank filter are crucial to filter media selection.

C.8.5.4.3 Instrumental measurements. A variety of ambient air instrumentation and measurement technologies have been developed to support the USEPA ambient air programs and serve as criteria pollutant monitors. Many of these vendor instruments and monitors have been granted equivalency status by USEPA to monitor for criteria pollutants such as nitrogen dioxide (NO₂), sulfur dioxide (SO₂), ozone (O₃), and PM-10. These instruments have met the equivalency criteria set by USEPA and will generate equivalent results if performed following the specified operating requirements. For other ambient air sampling uses, the instrument selected for the measurement must meet the project DQOs.

C.8.5.5 Sample preservation and handling. Methods for preservation of whole air and sorbent samples range from the simplified canister, which is shipped at ambient conditions, to the enclosure and low temperature maintenance of recovered VOC collection cartridges. Factors to be considered for sample preservation include the sample contaminant loss and degradation during storage and shipment, sample media breakdown or breakthrough, etc. The EPA Compendium Methods (EPA/600/4-84/041, EPA/625/R-96/010b) may not identify the sample preservation necessary for all site specific samples or environments. Additional measures may be necessary, such as the storage of flexible VOC bags or collected resins within enclosed containers, or aluminum foil for protection from photodegradation.

C.8.5.6 Collection of adequate field control samples. Field control samples are collected to verify that the sampling system is interference-free and to determine whether the data are of acceptable quality. For ambient air sampling, recommend a variety of blanks be incorporated to evaluate the sampling and measurement system. These include evacuated canisters and resin collection media blanks, reagent sampling, and recovery blanks. When site conditions exist that may invalidate or jeopardize results, recommend the collection of backup samples (i.e., VOC) in series with the method media.

C.8.5.7 Sampling methods. There are seven codified USEPA methods (40 CFR Part 50), including total suspended particulates, carbon monoxide (CO), SO₂, O₃, NO₂, lead (Pb), and particulate matter less than 10 microns (PM-10). USEPA also allows the use of equivalent measurement methods for ambient air criteria pollutant monitoring. When these methods serve compliance monitoring, include quality control procedures and results to support the data quality required. The QC procedures outlined within several standard methods may serve as a guideline for air methods that do not specify appropriate QC procedures. Other EPA ambient air methods used for HTRW projects have been published as EPA guidance methods within USEPA (EPA/600/4-84/041, EPA/625/R-96/010b). These methods are referenced as the "TO" methods and include TO-1 through TO-17. For inorganic matter parameters that can be used for HTRW projects, the USEPA has published guidance methods (EPA/625/R-96/010a).

C.8.5.8 Decontamination procedures. Decontamination procedures for ambient air sampling applies to the sampling apparatus and the reuse of sample containers (i.e., summa canisters or flexible bags for whole air samples). Decontamination of apparatus is accomplished by flushing the equipment with a inert gas until the system is found to be interference-free. If flushing the system is ineffective, more thorough procedures for decontamination as identified in Instruction E-6 of Appendix E should be used. Decontamination of flexible bags may be accomplished by a series of inflate-and-deflate steps, using the inert gas until the filled

bag is analyzed and found to be contaminant-free. Generally, filling and evacuating three successive times is taken to be acceptable. For any given site application, this should be confirmed.

C.8.5.9 Documentation requirements. Documentation requirements for ambient air sampling should encompass all aspects of the site setup and sample collection and handling as outlined within this instruction and in Instruction F-1, Appendix F. This includes documenting the sample equipment and apparatus preparatory phase inspection and quality check before field activities begin. Sampling equipment calibration may include volumetric measurement devices and flow controllers. Certification of VOC sampling systems include equipment certification. The cleanliness of each lot of precleaned sample containers or collection media should be verified by the container supplier or the laboratory, and appropriate paperwork (i.e., certificates) retained with other field documentation.